DOCUMENT RESUME

ED 305 227 SE 050 405

AUTHOR Heaney, John, Comp.
TITLE Better Science: How To Plan and Manage the Curriculum. Curriculum Guide 5.
INSTITUTION School Curriculum Development Committee, London (England).; Secondary Science Curriculum Review, London (England).
SPONS AGENCY Association for Science Education, Cambridge (England).
REPORT NO ISBN-0-435-54821-2
PUB DATE 87
NOTE 49p.; For the curriculum review see SE 050 400; for other curriculum guides in this series see SE 050 401-412.
AVAILABLE FROM Heinemann Educational Books, Inc., Halley Court, Jordan Hill, Oxford OX2 8EJ, United Kingdom ($44.40 English pounds per set).
PUB TYPE Reports - Descriptive (141) -- Viewpoints (120) -- Guides - Non-Classroom Use (055)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Curriculum Development; *Educational Improvement; Elementary Secondary Education; Foreign Countries; Instructional Development; *Instructional Improvement; *Science Curriculum; Science Departments; Science Education; Science Instruction; Science Teachers; *Secondary School Science
IDENTIFIERS *United Kingdom

ABSTRACT

This publication is one in a series of 12 giving the recommendations that were made for a broad and balanced education program in science for young people. Section one of this guide discusses consulting and negotiating both with colleagues and others. Sections two and three address the timetabling issue. Section four explains a strategy that a science department might adopt in designing its curricular framework. Section five discusses the presentations of science as separate subjects or as a fully integrated subject. Section six discusses the sequence of learning events experienced by individuals and groups during a course. Sections seven and eight deal with the politics of curriculum change as it relates to science education. An introduction and references are provided. (RT)

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SECONDARY SCIENCE CURRICULUM REVIEW

SSCR

BETTER SCIENCE:

How to plan and manage the curriculum

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Curriculum Guides

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SECONDARY SCIENCE CURRICULUM REVIEW

SSCR

BETTER SCIENCE:

How to plan and manage the curriculum

Curriculum Guide 5

Compiled by John Heaney

Heinemann Educational Books/Association for Science Education
for the School Curriculum Development Committee

The Secondary Science Curriculum Review has run from 1981–1986 (Phases 1 and 2), with a dissemination phase (Phase 3) from 1986–1989.

The Review operates under the aegis of the School Curriculum Development Committee and is supported by the Association for Science Education. In addition, it receives or has received support from the Department of Education and Science, local education authorities, the Schools Council (Phase 1), the Northern Ireland Council for Educational Development (Phase 2), the Health Education Council (Phase 2), industry (particularly British Petroleum), the Department of Trade and Industry and the Independent Broadcasting Authority.

Acknowledgements

The ideas presented in this Guide are not only the result of the work of SSCR groups. Their production has also relied on considerable discussion in, and on the collective wisdom of, the SSCR Central Team:

Beverley Bell (CLIS Project Coordinator 1984–85), Di Bentley (Research and Development Officer, Health and Science Education 1983–86), Paula Bower (Information Officer 1984–86), Christine Ditchfield (Southern Regional Project Officer), Dave Ebbutt (Evaluation Officer 1983–86), Kate Ellington (North West Regional Project Leader 1983–86), John Heaney (Midlands Regional Project Officer), Joseph Hornsby (North Regional Project Officer), Ruth Jarman (Northern Ireland Regional Project Leader 1983–84), Jeff Kirkham (Director from 1986; Director Designate 1985–86), Anna Larter (Project Administrator), Mick Michell (Director 1985–86; Deputy Director 1982–85), Val Oldham (CLIS Project Coordinator 1985–86), Denis Stewart (Regional Project Officer Wales & West Midlands from 1986; Northern Ireland Regional Project Leader 1984–86), Jeff Thompson (Chairman, SSCR Steering Committee), Mike Watts (Anglia Regional Project Leader 1983–86), Dick West (Director 1981–85), Cathy Wilson (ASE/SSCR Liaison Officer).

The compiler is very grateful to the following for their substantial contributions; Christine Edwards, Joseph Hornsby, Mick Nott and Denis Stewart; to the Curriculum Frameworks Advisory Committee for ideas on which the guide was based: Martin Baxter, Christine Edwards, Kate Ellington, David Finney, George Goldby, Joseph Hornsby, Giles Job, Derek Lewis, Mick Nott and Malcolm Oakes; and to SSCR local working groups. The compiler also thanks Paul Black and Jeff Kirkham for their advice, and Margaret Boam for her support and assistance.

The publishers would like to thank the following for permission to use extracts from other publications: The ASE for extracts from *Planning for Science in the Curriculum*; the ASE and Malcolm Frazer for extracts from his Secondary Science Curriculum Review lecture; the ASE and Paul Black for extracts from his presidential address on 'Integrated or Coordinated Science'; the Department of Education and Science for extracts from *Science 5–16: A statement of policy*; Bury LEA and Suffolk County Council Education Committee for quotations from their responses to DES Circular 8/83; A.P. Sanday for extracts from *The Modular Curriculum and Educational Issues*.

Heinemann Educational Books Ltd
22 Bedford Square, London WC1B 3HH

LONDON EDINBURGH MELBOURNE AUCKLAND
SINGAPORE KUALA LUMPUR NEW DELHI
IBADAN NAIROBI JOHANNESBURG
PORTSMOUTH (NH) KINGSTON

The Association for Science Education,
College Lane, Hatfield, Herts.

ISBN 0 435 54821 2

© SCDC Publications 1987
First published 1987

Typeset by Castlefield Press, Wellingborough, Northamptonshire.
Printed and bound in Great Britain by
Scotprint Ltd., Musselburgh.

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Foreword

This is the fifth in a collection of twelve Curriculum Guides from the Secondary Science Curriculum Review, published jointly by Heinemann Educational Books and the Association for Science Education.

A *Directory of Resources* and a book, *Better Science: Making it happen*, which tries to set the Review's recommendations in the context of the whole school, will appear at the same time as the Guides. These will, when taken with earlier and forthcoming SSCR publications, including those from local groups, constitute the recommendations which the Review is making towards a broad and balanced science education for all the young people in our schools. The series title 'Better Science' is thus both apposite and self-explanatory. It is hoped that the current phase of the Review (1986–89) will achieve successful implementation of the recommendations.

But what is the status of these new publications apart from reflecting the formal approval and support of our major sponsors, the School Curriculum Development Committee and the Association for Science Education? From what sources have the recommendations within them emanated? Those readers unfamiliar with the history of the SSCR will find it explained within the Guides; but most will be aware that it set out as a project which tried fully to involve the practising teacher in the development of solutions to the problem of science for all. Thus, although the Guides have been compiled principally by the Central Team of the Review, they draw on the work of thousands of teachers in working groups over the past four years. Although the work of many of the groups is referred to in the Guides, it is not possible to refer to it all. In the *Directory of Resources* readers will find details of what many of these groups have produced. The writing of these Guides, however, would not have been possible without the groups' existence and the Review Central Team hopes that the content of the Guides truly reflects their work. Thus the pronoun 'we', used within them, often reflects the view, gleaned over five years of consultation, of the practising teachers involved with the Review. On other occasions it can represent the views of the SSCR as constituted by the Central Team and Steering Committee and it is hoped that particular usage will be apparent from the context.

Jeff Kirkham
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Introduction: the issues

A plethora of terms have been used to describe school science courses. In the *GCSE National Criteria* documents (**0.1**) for example we find reference to coordinated, combined, integrated, unified, associated, directed and modular courses. In discussion of ways of achieving broad and balanced science courses for all we hear much talk of core components and options, science and further science, and so on. The ASE document, *Planning for science in the curriculum* (**0.2**) mentions spiral and stratified models among others. One suspects that all this jargon may have confused rather than clarified the issues of curriculum organisation and course planning.

We think that people are often at cross purposes when they argue the relative merits of different types of courses. Are they always talking about the same things? Is modular science for example really an alternative to integrated science? We think not. Indeed we are sure you can quite easily have the best of both worlds – a modular integrated science course! You could equally well adopt a coordinated approach within a modular programme. If modules do not appeal then why not try a linear structure? You can still adopt either an integrated or a coordinated approach or compromise on a combined science version.

Does all this leave you feeling confused? If so, we hope that the titles of four of the sections of this guide will make clear our intention to try to remove such confusion:

1 *The place of science in the school timetable* (Section 3);
2 *Organisation of the subject matter* (Section 5);
3 *Programming the learning – linear or modular courses?* (Section 6);
4 *Contexts for science learning* (Section 7).

By the school timetable we mean quite literally the document produced annually which goes by that name. It indicates the amount of time allocated to each 'subject' for each group of students and at what point in the school week these pieces of time occur. It also indicates how teachers are deployed and rooms are allocated. It says nothing explicit, although much may be implied, about what actually happens in those timetable slots and how they relate to each other. Some timetables allow considerable flexibility usually by blocking students, teachers and accommodation. Nobody should be autocratic about the timetable; it is essentially a compromise between the varied demands and interests within the school and ought to be arrived at by negotiation. Section 1 is therefore about consultation and negotiation both with colleagues and others. The timetable in the sense described above is of course only one matter to be dealt with during the consultative process. Sections 2 and 3 address the timetabling issue more directly and specifically.

In Section 4 we look at the strategy a science department might adopt in designing its curricular framework. This section also deals with a whole set of issues which need to be thought about during that process and which are raised in the DES paper, *Science 5–16: A statement of policy* (**0.3**).

Section 5 is about the subject matter of science. It can be presented as separate subjects – biology, chemistry and physics, and perhaps others – or as a fully integrated subject, and there are of course many possible compromises in between. The extent to which this organisation is reflected in the timetable varies from school to school.

Section 6 is about the sequence of learning events experienced by each individual and group during a course. This structure could depend entirely upon the individual teachers in charge of classes but we do not think that would be a sensible or happy situation!

In Section 7 we come to the business of context. Let us assume for the sake of argument that there is some body of knowledge, skills and attitudes that ought to form the basis for a science course. There are various ways these can be presented, different viewpoints, different frames of reference, that is to say different contexts. A course is made up of a series of learning experiences which could be thought of as scenes in a protracted drama. Using this analogy we can think of the course content as the plot. The contexts then are the stage sets; the same one may last throughout the play or changes may be made from act to act or scene to scene.

Section 8 looks briefly at the present situation in schools and the ideas that LEAs have about future development. The section is based upon LEA curriculum statements.

The following diagram (Fig. 1) indicates how the sections in this guide relate to each other. This introduction and Section 8 stand on their own but the interconnections between the other seven sections are somewhat complex.

It was originally intended that this guide should include a section about the whole curriculum perspective. It was found however that this aspect was so intimately related to a whole range of other issues treated that it was impossible to separate it without tedious repetition. The decision to exclude that section therefore reflects, somewhat paradoxically, the intrinsic importance of the topic. Section 5 of *Planning for science in the curriculum* (**0.2**) is entitled 'The whole curriculum perspective'.

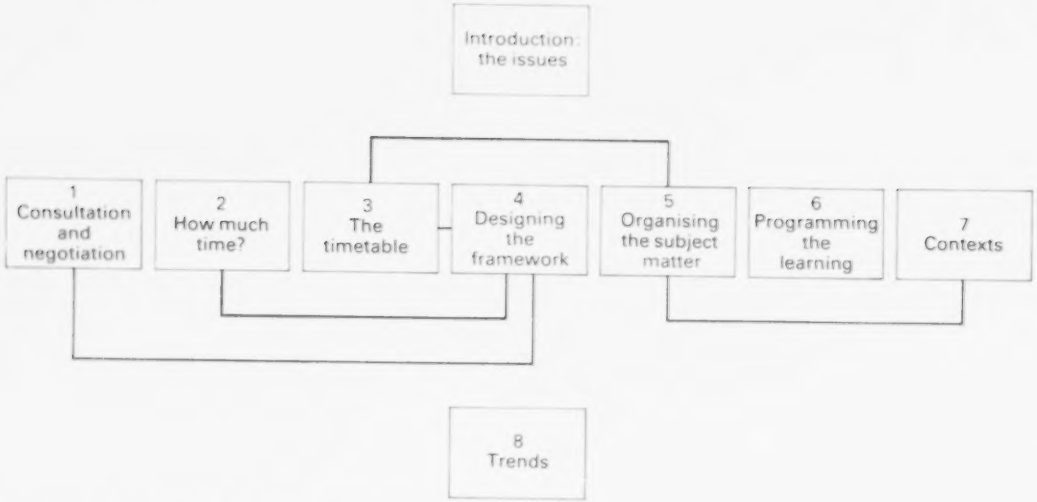


Fig. 1 Connections between the sections of this Curriculum Guide

SECTION ONE

Consultation and negotiation

Inhibitors of change

It has been said that there are three prime inhibitors of curriculum change. One of these is the **timetable**. This is discussed more fully in the next two sections and all that need be said at this stage is that any curriculum changes affecting the timetable must be the subject of consultation, negotiation, and perhaps compromise, with colleagues outside the department. It is this process of negotiation rather than the actual mechanics of timetabling, a relatively simple matter, which is the real problem. It is a time-consuming and sometimes difficult process but one that has to be firmly tackled when change is in the air. It is necessary because of the need to provide a balanced curriculum and to reconcile the various claims to curriculum time within the overall philosophy of the school and its organisational policy.

Tradition can be another inhibitor. We do not wish to use this term in a pejorative way. There is no sense in change for the sake of change and even where change is desirable tradition is the firm base upon which we should build. It only becomes an inhibitor when it is used as an argument for resisting change or, even more difficult to combat, if it becomes a subconscious obduracy in people's minds. That could affect not only teachers but also, and perhaps more importantly, students, parents, governors, potential employers and indeed the community at large. It is just as foolish to ignore tradition as to be hidebound by it. It is the duty of teachers, the curriculum experts, to explain clearly and patiently to interested lay people why the change they are proposing will improve the education they provide and why some content and methods which may have served the community well in the past are no longer appropriate.

The third inhibitor is the **insecurity** people feel when they venture into unknown territory. This is often felt very keenly by conscientious teachers who believe that they should play to their proven strengths in order to give their students good value. Feelings of insecurity at times of change can also inhibit students and their parents.

Difficult though negotiation about the timetable may be, because of the multitude of vested interests and potential areas of conflict between subject specialists, it is nevertheless a very concrete issue which lends itself to a logical approach. Tradition and feelings of insecurity, on the other hand, are more intangible factors – easy to recognise but much more difficult to engage with.

Who should be involved in negotiating the curriculum?

The process of change may be initiated within the **science department**, it may arise from a **whole school** review of the curriculum, probably led by the headteacher or a deputy head, or it may even stem from an **LEA** initiative, in which case the link person is likely to be one of the **advisory staff**. It is important who actually initiates the process; that person or group is powerfully positioned as far as the implementation of their ideas and aspirations is concerned. They can to a certain extent set the agenda and thereby the order of subsequent events. Later in this section we suggest a model for curriculum development in which the science staff take the initiative at an early stage in devising a draft set of aims and this model is further developed in Section 4. The procedure described is an arduous and time-consuming one but we would suggest that it is likely to be far more comfortable and satisfying for the scientists than having change imposed upon them. This is only one reason among many for science departments to take an *early*, *positive* and *active role* in the implementation of change.

These are internal agencies for change but there are also external influences on the curriculum. The most significant of these at present is the **Department of Education and Science** and its policy. In *Science 5–16: A statement of policy* (**0.3**) the DES calls upon the **Secondary Science Curriculum Review** to advise on how to implement the stated policy. But SSCR, and other curriculum development projects, are, it is to be hoped, also initiators of curriculum change themselves, although perhaps more often they provide a basis for development of changes initiated in the school. Two other external agents of curricular change at present are **TVEI** and **GCSE**.

Education is a partnership; it requires the active participation and cooperation of both teacher and learner. If **students** and their **parents** are teachers' clients, then young people have a right to an education appropriate to their needs, and parents and local education authorities share a statutory

duty to ensure that it is provided. The aims and objectives of parents and children reflect their personal aspirations and beliefs and at times their priorities will inevitably differ from each other's or from those of teachers. Who is to say that one view or the other is more legitimate or compelling? All three parties deserve to be involved in planning the educational process, with teachers perhaps playing a special, but not necessarily dominant, part because they are the experts, the professionals. They ought not to be autocratic but it is both their right and their duty to give well-informed advice. An ASE view (**0.2**) of the rights of students and of parents are shown in Box 1.

Of course it is the students, unlike most teachers, who actually experience a whole curriculum, even though that experience may well be different for each individual. So if we involve these young people in the consultation process we may and certainly ought to encourage a more holistic approach involving the whole school.

Students

(They are) the group with the biggest stake in education . . . They are entitled to consultation and a clear rationale for the curriculum. The consultation is by its very nature usually informal but students are less likely than they were to accept unquestioningly the curriculum set before them by their teachers. Disaffection with the curriculum is a spur for change and a negotiated curriculum will increase the sense of purpose shown by the students. We should welcome and respect the increasing sophistication and independence of mind of our young people.

Parents

Consultation and negotiation . . . are crucial, not only because they (the parents) have a right to be informed but also because they have a vital supportive role to play in their children's education. They cannot expect to negotiate effectively unless they understand and believe in the school's educational policy, its aims and methods.

Box 1 *Parents and students involvement in planning* (**0.2**)

Thus the arguments in favour of consultation and negotiation fall into two categories. There are the altruistic aspects – to do with the rights of individuals and groups – and the pragmatic aspects – to do with mobilising widespread support and engagement in the management of the curriculum.

A good school is an integral part of the community it serves; it should influence and be influenced by the community's culture. Although its most intimate and perhaps most important contacts will be through children and parents there are other people who have both legitimate interests in the school's activities and valuable help to offer. Some of these interests, but probably not all, will be represented on the governing body and it should not be forgotten that governors now have much greater formal responsibility for the curriculum than they once did.

It is essential that those organisations who will work with the young people when they leave school are kept fully and effectively informed and that their comments, suggestions and criticisms are taken seriously and discussed. These organisations include of course **potential employers** in industry and commerce and **institutions** of **further** and **higher education**.

Does consultation and negotiation lead to agreement and harmony?

The need for various people to work together on the planning, implementation, adoption and institutionalisation of a curriculum development is widely recognised. It is also recognised that when participants work together there are two processes which must be engaged in, namely consultation and negotiation. The two are usually put together (like eggs and bacon or assessment and evaluation!) but they are *not* the same thing.

It is *not* always possible for agreement to be reached within a school staff or department and yet decisions have to be made despite that. Not all members of the group have the same status and this can cause tensions and conflict The way power is distributed and the style of decision making influence how much harmony can be achieved. Consultation and negotiation are essential but everybody involved must be clear about their roles and the extent to which any particular discussion is consultative or negotiative.

Before consultation starts

There are several important ASE publications concerned with the negotiation and management of change in school science. These include *Alternatives for Science Education* (**1.1**), *Education Through Science* (**1.2**), *Decisions in the Science Department* (**1.3**) and *Planning for Science in the Curriculum* (**0.2**). The last two are primarily concerned with in-service education and training for teachers relating to curriculum management and development. *Planning for science in the curriculum* proposes detailed frameworks for the consultation process.

(i) The identification of areas of concern
(ii) the analysis of problems and the articulation of possible solutions
(iii) the implementation stage itself

The development process is included within stages (ii) and (iii)

Box 2 *Stages in the negotiation of change* (**0.2**)

It suggests that there are three stages in the negotiation of change (see Box 2).

The identification of at least some areas of concern may have sparked off the process of change. Closely related to them will be the articulation of a **set of aims**, probably by an individual or group among the science teachers. It is best if the whole department can agree about aims before detailed discussion is extended to outsiders. A set of aims is a 'statement of intent' (**0.2**) which

> *states in broad terms what the educational process is designed to achieve. It hints at the totality of experience on offer and outlines possible routes to the desired goals. Without a good set of aims a school or department is unlikely to have a real sense of purpose.*

Throughout its life the SSCR has been guided by the aims which were first published in 1983 (**1.4**). These are set out in Box 3.

We offer these as a basis for the aims of a school science course. They may well have to be modified or extended because it is important that they reflect the aims and philosophy of the school. There is of course always a danger that once they have been formulated the aims will be ignored, misinterpreted or only paid lip-service. To avoid this **a set of criteria** should be devised, perhaps in the form of questions, to judge whether the aims are being put into practice. They can subsequently be used to evaluate the syllabus, schemes of work, classroom practice and the quality of learning of the students. **A rationale** should also be written **which relates the criteria to the aims**. In practice it is necessary, before writing the criteria, to devise a very detailed **set of objectives** which are compatible with the aims and which reflect the skills, processes, attitudes and knowledge that it is intended the students should acquire (see Fig. 2).

Fig. 2 *The relationship between aims and objectives*

If at all possible, this process should be completed *before* the science staff present the aims, criteria and rationale to the other consultants. This pre-planning is desirable in order to enable those consulted to interpret what the curriculum will be like when it is in action, but it is probably not helpful to circulate the detailed objectives widely at this stage. What outside consultants need is a clear **summary** of the thinking that has taken place. The science staff, however, do need to have a good idea of how learning experiences are going to be structured, the assumptions about learning that underlie that structure and the criteria by which teachers will judge formatively and summatively their teaching and their students' achievements. Without this depth of understanding the science team will not be able to play its full part in interpreting the new aims and their consequences when full consultation begins.

Schools (should) provide . . . adequate opportunities for all students to:

a) explore the nature of the biological environment through observation, experiment and systematic enquiry;
develop the ability to design and carry out experiments, evaluate evidence and solve problems;
study the key concepts and principles of science that are essential to an understanding of science as a way of looking at the world;
study those aspects of science that are essential to an understanding of oneself, and of one's personal well being;

b) use their knowledge of science to design and develop solutions to technological problems, to test and evaluate those solutions and to cost such exercises;
study the key areas of science and technology that relate to the world of work and leisure so that they are better able to participate in a democratic society;
study key concepts that are essential to an understanding of the part science and technology play in a post-industrial and technological society;

c) gain some understanding of the historical development and contemporary cultural significance of scientific principles and theories;
appreciate that technologies are expressions of the desire to understand and control the environment and that technologies change in response to changing social needs;
appreciate that past scientific explanations were valid in their time and that early technologies are still valid in some cultural contexts;

d) discuss, reflect upon and evaluate their own personal understanding of key scientific concepts, theories and generalisations;
explore topics or themes which exemplify the limitations of scientific knowledge as an explanation of the human condition.

Box 3 *The SSCR aims* (**1.4**)

It is inherent in all that has been said in this section that the science staff in a school cannot function in isolation from their colleagues and indeed that the science taught is an integral part of the whole school curriculum; this has implications for planning. Working on your own is probably quicker in the short term, and certainly less enervating, but it severely limits the extent and type of change and development that can occur. Whole school planning takes longer and is more difficult but may be essential in the long run. In Section 3 we suggest a way in which technology

can be used across the curriculum, involving the cooperation of several departments or subject areas. This kind of development would be impossible without whole school planning. It must not be forgotten that the students are the school's *raison d'etre* and their experience is of the whole school and the whole curriculum.

SECTION TWO

How much time for science?

DES recommendations

The Department of Education and Science in its policy document *Science 5–16: A statement of policy* (**0.3**) recommends the allocation of 'about 10 per cent of total curriculum time to science in the first two years (of secondary education) and about 15 per cent in the third year'. This is already the norm in many schools although some do have more time in years 1 and 2.

Much more controversial is the later statement that:

> *. . . the only way in which the claims of a broad and balanced science education, and those of a broad and balanced total curriculum, (can) be reconciled (is) by a* maximum *time allocation for science of about 20 per cent of the total curriculum time . . . in years 4 and 5.* (**0.3** para.75)

The SSCR view

The Secondary Science Curriculum Review would wish to add that it is not feasible for any student to gain a broad and balanced science education appropriate to her or his ability in *less* than this time. In other words *everybody* should spend about the following amount of curriculum time studying science at secondary schools:

10 per cent in year 1
10 per cent in year 2
15 per cent in year 3
20 per cent in year 4
20 per cent in year 5.

Implications for the more able students

Naturally enough these proposals cause misgivings. There are fears that if our most able students cannot study the three separate sciences, each for the length of time normally allocated at present for GCE O level courses, there may be a drop in standards. Potential academic and professional scientists may, as a result, find it more difficult to cope with A level and degree courses. Professor M.J. Frazer in his 1986 Secondary Science Curriculum Review Lecture (**2.1**) to the ASE did not share this view and had this to say:

> *. . . the loss in content at 16 can easily be made up in the two years of an A level course . . . I think the reduced content will have no adverse effect on degree courses. Indeed the changes at GCSE level will be of benefit – students will come with enhanced skills and with a more balanced view of science. With everyone studying all the sciences there will be more chances of more students deciding to take some science at A level and beyond.*
>
> *My justification for asserting that the shortfall in content can be made good in two years are: (i) students taking A level are more motivated and will learn more quickly; (ii) they are more mature; (iii) they will have developed skills which will allow them to learn the content more easily as they need it.*

We would also like to point out that the present structure of science courses to 16+ provides no guarantee that students bring to their A level courses common experiences, skills and levels of understanding as a basis for development. It is interesting to note a study reported in *The Times Educational Supplement* (**2.2**) in which the A level performance of SCISP students is compared with a matched sample of two-science O level students. It found that the SCISP students did slightly but significantly better in physics and biology although slightly less well in chemistry. The SCISP students will of course have spent approximately two thirds of the time spent by the three-science students on each of the separate sciences but their studies were presumably more balanced and probably more process-oriented.

Far from causing falling standards we think that the reforms proposed by DES and SSCR will enhance standards. The quantity of detailed factual knowledge may fall for a minority of our students but we are convinced that the quality of learning and the level of understanding of *all* students, including the most able, will greatly improve. The aim is that students will be better at transferring and applying their knowledge because they will rely much more on understanding realised through a more positive development of skills and processes and less on memorisation.

Implications for the less able and the poorly motivated

There are worries too about the other end of the ability range and about poorly motivated students

of whatever ability. Many experienced teachers ask how they can be expected to interest, occupy and control poorly motivated youngsters for an even bigger slice of time than they have to cope with already. The answer is that new approaches should improve motivation and will also demand more time. Too often under-achievers are expected to spend most of their time doing the very things they find most difficult and discouraging. These are memorising and writing. We want to shift the emphasis to more rewarding activities. It is not only the students who achieve the most success in conventional school terms who are good at problem solving, for example. If teachers can pose problems that are interesting, open and accessible to students, they provide them with opportunities to record positive achievement and to show what they can do to the best of their abilities.

How should the students spend their time?

All students, whatever their ability, should be offered process-led courses designed to enhance technological, as well as scientific, awareness and capability. The work should be more obviously relevant to themselves and to the environment and community in which they live. There should be a much greater variety of experiences than many of them are offered today. These will include **small group** work with plenty of **discussion**, meaningful **practical work** that they can have a hand in planning, **problem solving**, **investigations**, **projects**, **individual research** work and **reading**. These and other possible activities are discussed in the SSCR Curriculum Guide, **Better Science**: **Approaches to teaching and learning**.

Most of the approaches described, designed to interest and engage the students, are also time-consuming and this type of approach combined with the requirement for breadth and balance means that plenty of time must be available. These activities, which cannot be rushed if they are to be of value, will use up a large proportion of the total curricular time available and so it really is important to reduce the content while increasing the allotted time. Of course it is also true that many of the activities – problem solving is a good example – are best tackled when *substantial, uninterrupted blocks of time* are available. It can often be very frustrating for both teachers and students if an interesting activity is brought to a premature, albeit probably temporary, conclusion by the bell! So schools ought perhaps to be giving serious thought to the structure of the school day.

There is one particular activity upon which we wish to focus briefly, namely **individual reading** by students. It probably receives less attention and time than it deserves in science lessons. The most common reading task that science students engage in is following instructions for practical work in the form of worksheets and the like. The work of the Schools Council Reading for Learning Project (**2.3**) suggests that this is rarely done well – most science teachers would probably agree. Unless children want to discover information and ideas from their reading they tend to read in a mechanical, often very quick way and fail to internalise the text. They need to be persuaded continuously to reflect on their reading as they go. There are various well-tried techniques available to teachers which help to structure this type of reflective or active reading and they are described in some detail in the reference cited above (**2.3**). The Reading for Learning Project found that if teachers promote **active reading**, through appropriate support, direction and techniques, it can be a very valuable motivator and develop important scientific processes. Students of a whole range of abilities can develop research and data analysis skills and become more able to benefit from resource-based learning. Like everything else, learning active reading takes time and so too do the further activities which its mastery makes possible.

Resource implications

There is one difficulty which should not be minimised. Most students will be doing more science and this will make heavy demands on teachers, technicians, accommodation and resources. Because of the novel teaching and learning techniques which need to be introduced there will be much need for well organised INSET. The problem of finding enough laboratory accommodation is particularly serious and it is certainly one that is worrying a lot of teachers. It can only be marginally alleviated by taking some of the activities that we recommend out of the laboratories (it may even be that some of them can take place outside lessons formally labelled 'Science'). The resource implications of our proposals are treated in more detail in the SSCR report, **Better Science**: **Key proposals**.

Implications for the timetabler

If one accepts that the overall timetable provision for science should be the same for everybody and that the factors discussed above should influence our planning, then timetabling becomes much simpler. The requirements for depth and balance do actually simplify the situation because they remove the completely open-ended option system. In effect the choice in the fourth and fifth years reduces to:

either a large core;

or core + options (from which students *must* select more science).

How the core is subdivided can then be decided and administered within the science department or teaching team. This flexibility allows different ways of realising the curriculum aims. Practical considerations such as availability of laboratories and apparatus must be taken into account in arriving at a decision. So too must the amount of responsibility that it is reasonable for different teachers to take; clearly an experienced teacher should be given more autonomy than a probationer or supply teacher or indeed a teacher who, though experienced, is new to the school. The general policies of the school and the department will also influence the solution adopted.

Section 3 looks in more detail at the place of science in the school timetable while Sections 5, 6 and 7 deal with some of the issues facing those who plan the science course itself.

SECTION THREE

The place of science in the school timetable

Departmental teams and individual teachers within them usually exercise a large measure of control over how the subject matter of a course is organised, how the learning is programmed, and how the work is presented and managed in lessons. They have much less direct control over the general organisation of the timetable and the allocation of timetable slots and spaces to different subjects. Decisions about the allocation of students to courses and groups according to their ability and achievement are also very often made outside the department. As has been explained in Section 1 all this must inevitably be a matter for consultation and negotiation with colleagues.

Criteria for effective timetabling

For the purposes of this section we take it as axiomatic that schools should provide broad and balanced science courses for all students up to the age of sixteen at least. We use the terms breadth and balance as they are explained in *Science 5–16: A statement of policy* (**0.3**) and we comment rather more fully on these in Section 5. Furthermore, we assume that schools will aim for the time allocations recommended by SSCR, namely about 10 per cent in the first two secondary years, 15 per cent in the third year and 20 per cent in years 4 and 5. The evidence available makes it quite clear that few schools as yet satisfy these criteria. This was apparent from the HMI secondary survey (**3.1**) and although we think there has been some improvement since then the same basic problems remain.

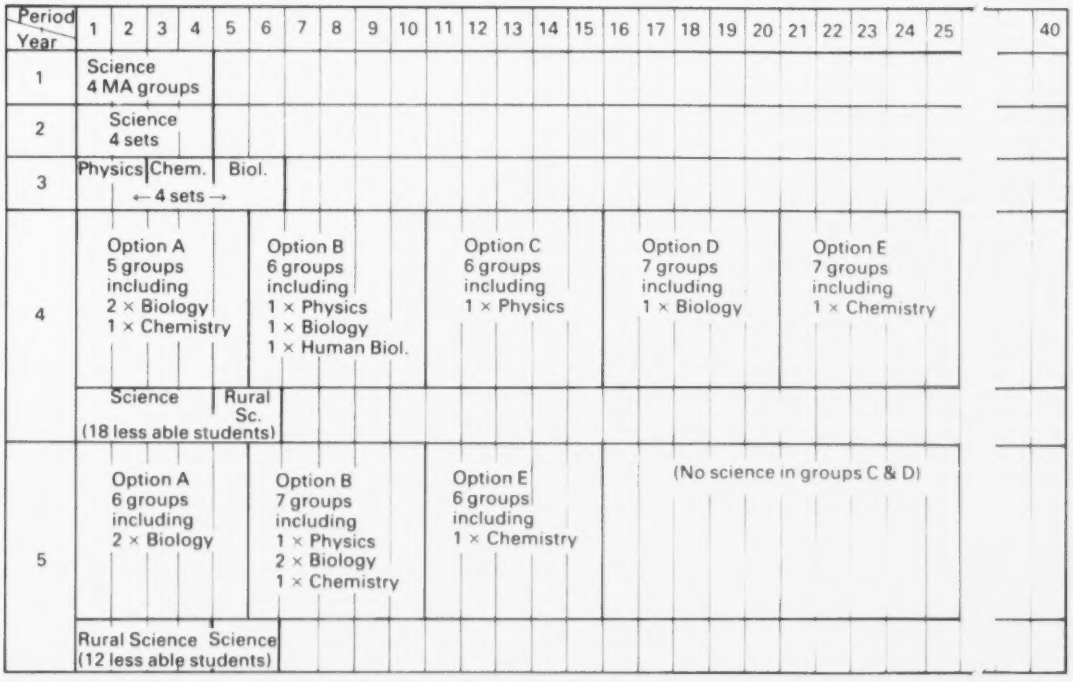
From the timetabler's point of view the simplest system is for all students in any particular year to do the same amount of science each week and for this science, as far as the timetable is concerned, to be undifferentiated. It would be part of the **core** as mathematics, English, PE and RE usually are now in British secondary schools for students up to the age of sixteen. Any refinements of this simple pattern can be left to the subject teachers concerned, preferably in consultation with colleagues. In practice however a very obvious feature of the curriculum in most secondary schools, especially in years 4 and 5, is its extreme complexity. It may be that schools are already striving to satisfy the criteria mentioned above but they are constrained by a whole host of other criteria too, often ones that are imposed from outside. Some schools have attempted to achieve breadth and balance by curious timetabling devices such as weeks with seventy five periods of twenty minutes each or 'weeks' that have more than the usual number of days! These devices are quite legitimate attempts to solve complex problems but administrative solutions must not be allowed to dominate the curriculum nor to create new problems. We think it is time to stop trying to reconcile conflicting demands and to concentrate on what we believe to be the major issue, namely breadth and balance in the curriculum as a whole and in its constituent parts including science. As we have implied in the previous section we ought perhaps to be seeking opportunities for students to engage in creative work for relatively long and uninterrupted periods of time. Later in this section we explore some possibilities for cross-curricular work in such extended periods.

In search of solutions – some schools' answers

As part of our attempt to gain an overview of the present situation we have studied 39 reports of full inspections made by HMI between 1982 and 1984, covering 25 LEAs (**3.2**). Each of these reports contains a detailed curriculum analysis. Very few of the schools concerned met our criteria at the time they were inspected although some did. Others met the criteria in part or could achieve them without much major restructuring of the timetable. We have selected six examples for discussion to exemplify what we mean.

The science curriculum in School A (Fig. 3) for the first three years is undifferentiated and meets our criteria of breadth, balance and time available. It is very flexible in years 1 and 2 because the classes are blocked and can therefore be setted or grouped in whatever way the science staff feel appropriate (although in practice the department did not appear to make such decisions internally). Some of this flexibility is lost in the third year when the separate subjects are timetabled. Timetabling the whole block as science with a cross-subject team of teachers would allow the subject-based teaching to continue but would also enable the team to experiment with other ways of organising the subject matter and programming the learning.

In years 4 and 5 a traditional options pattern comes into operation and this does not meet our criteria. In 25 per cent of curricular time only two of the three science subjects can be studied and this does not provide appropriate breadth and



MA = mixed ability

Fig. 3 *The place of science in the timetable: School A (Hereford and Worcester, 1984)*

balance. In a few cases the combination of biology and human biology is allowed which is particularly narrow! It is of course possible to opt for all three sciences, and some do, but only by greatly exceeding the recommended time for science to the detriment of the remainder of the individual's curriculum. Moreover it is possible to study only one science or even, as some students do – about 10 per cent at the time of the inspection – to opt out of science completely at this stage. On the other hand it is interesting to note that overall 20 per cent of student time is spent on science in year 4 and nearly as much in year 5. So from an administrative point of view the resource implications of 20 per cent science for all (the allocation of rooms, teachers and students to each other) would appear to be minimal. The implications may of course be massive from the personal points of view of individuals, however, and so we are not suggesting that any change would be easy.

There are two ways in which this curriculum could be modified in years 4 and 5 to meet SSCR criteria. Firstly the number of science subjects available within the options pattern could be reduced from four to two, say physical science and biological science or science and further science, and all students would have to study both. This of course would require individual teachers to broaden their subject bases. All students would actually be getting 25 per cent science, two periods a week more than the recommended 20 per cent. Alternatively two of the option groups could be replaced by a core science course of 8, 9 or 10 periods per week, continuing the pattern of the first three years. This of course would mean that the other subjects in the option pattern would be squeezed into a smaller range of options. This might create a lot of tension in the school which would in all likelihood have to be resolved by a *whole curriculum review* – probably no bad thing! One possibility within a core science structure would of course be a coordinated three subject approach which would allow teachers to remain with their specialisms.

School B (Fig. 4) is actually far from typical in its population. It is a girls' grammar school and therefore has of course a relatively narrow ability range. Nevertheless the timetable structure is of interest and is in fact very similar to school A. There are two important differences. Firstly, each option block in years 4 and 5 occupies only four instead of five periods – a time which might make the eventual conversion to 20 per cent for all more manageable. Secondly, all students are already required to study at least one science. This does not ensure 20 per cent science for all, nor does it ensure balance, but it is a step in the right direction. The average time spent on science is slightly more than 20 per cent so, like school A, reorganisation to provide breadth and balance should not place an intolerable administrative strain on staffing and resources.

School C (Fig. 5) is a much bigger school than either A or B and its curricular organisation, set up after a structured curriculum enquiry, is very complex. In the first three years students are

Period / Year	1 2 3 4	5 6	7 8 9	10 11 12	13 14 15	16 17 18	19 20 21	22 23 24 25	39 40
1	Science 4 MA groups								
2	Science 4 MA groups								
3	Physics Chem. ← 5 sets →	Biol.							
4	Option 1 6 sets including 1 × Biology 1 × Chemistry	Option 2 6 sets including 1 × Physics 1 × Chemistry	Option 3 6 sets including 1 × Physics 1 × Biology	Option 4 6 sets including 1 × Biology 1 × Physics	Option 5 6 sets including 1 × Biology	Option 6 7 sets including 2 × Chemistry			
5	Option 2 5 sets including 2 × Chemistry 1 × Biology	Option 3 7 sets including 2 × Chemistry 2 × Biology	Option 5 7 sets including 2 × Physics	Option 6 6 sets including 1 × Biology	No science in Options 1 or 4				

MA = mixed ability

Fig. 4 *The place of science in the timetable: School B (Birmingham, 1984)*

Period / Year	1 2 3 4	5 6 7 8 9	10 11 12 13	14 15 16 17	18 19 20 21	22 23 24 25	39 40
1	Science 6 classes in BAND 1 4 classes in BAND 2						
2	Science 6 classes in Bd 1 4 classes in Bd 2 2 classes in Bd 3						
3	Physics Chem. 4 classes in Bd 1 4 classes in Bd 2 2 classes in Bd 3	Biol.					
4	A	B includes 1 × P, 2 × C sets	C	D	E includes 2 × C, 1 × B set	F includes 2 × P, 1 × C, 2 × B sets	
	G	H	J	L includes 3 × Sc sets	K includes 2 × P, 1 × C, 2 × B, 2 × Sc sets	M	CORE
	Science (less able group)						
5	A	B includes 2 × C, 1 × B set	C	D	E includes 1 × P, 1 × C sets	F includes 2 × P, 1 × C, 2 × B sets	
	G	H	J	L includes 3 × Sc sets	K includes 1 × P, 1 × C, 2 × B, 1 × Sc sets	M	CORE
	Science (less able group)						

Fig. 5 *The place of science in the timetable: School C (Sandwell, 1983)*

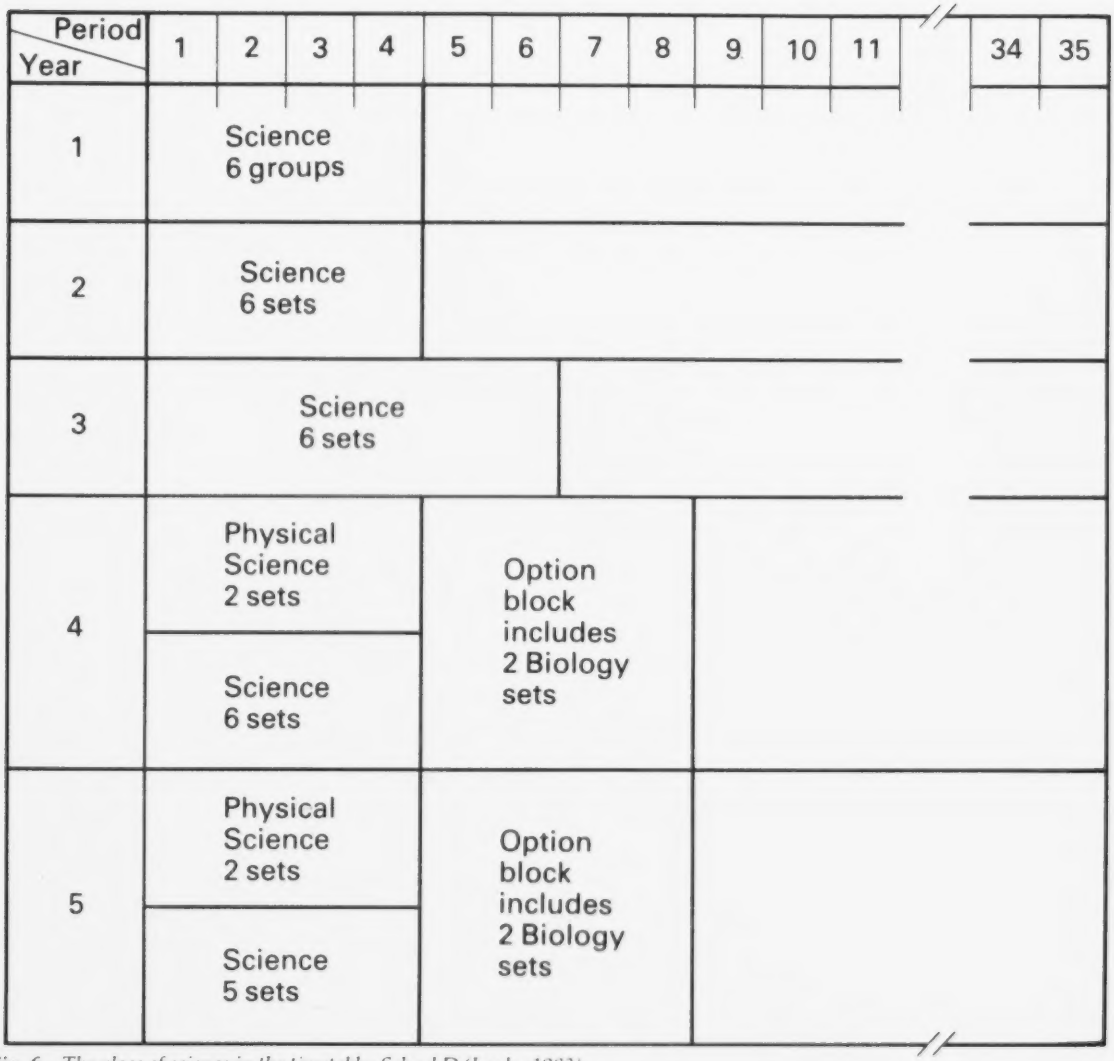
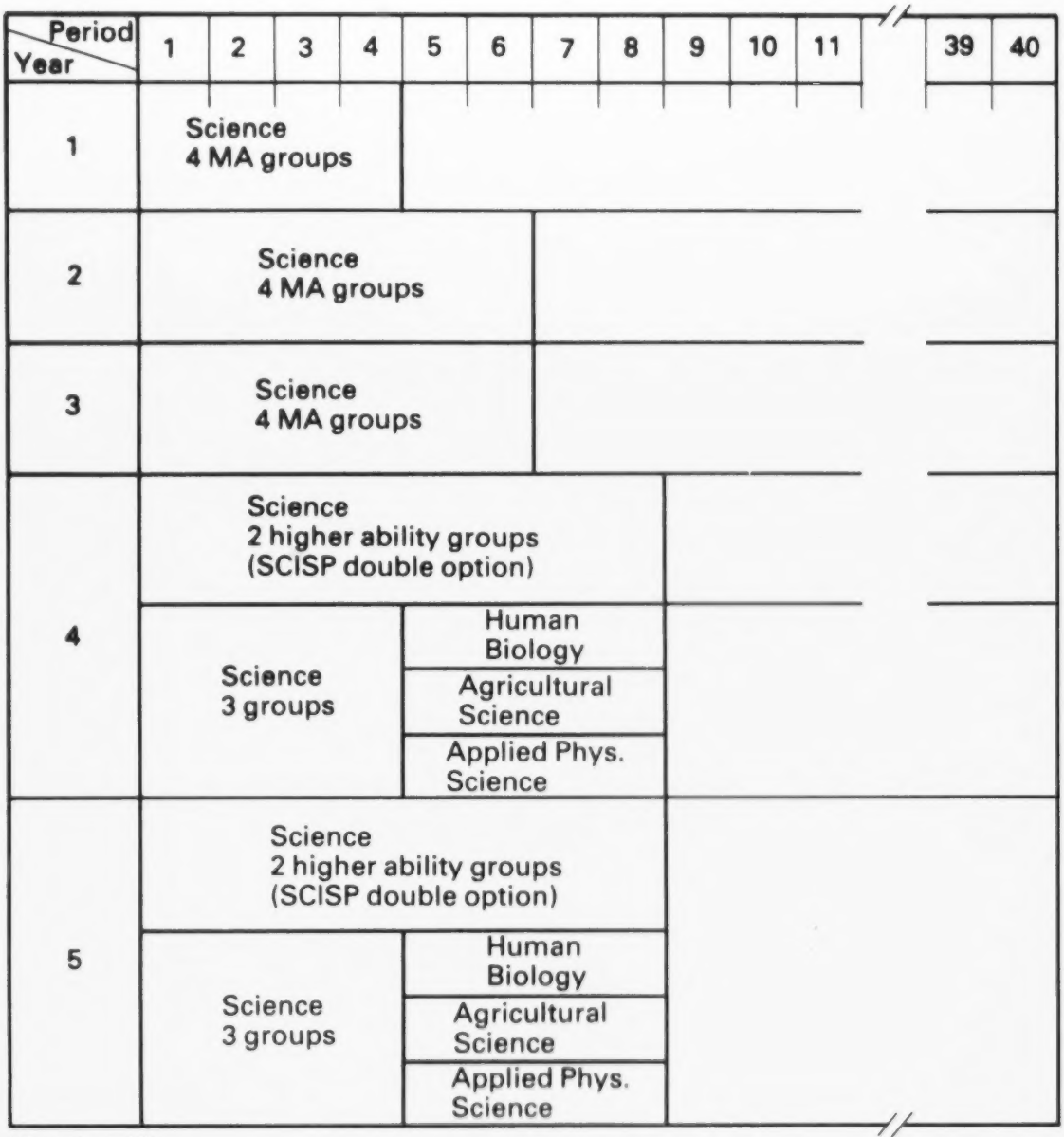


Fig. 6 *The place of science in the timetable: School D (Leeds, 1983)*

banded and in years 4 and 5 an intricate options pattern operates whereby students may study either four, five or six subjects in addition to the core of 16 periods. Students are required to select at least one science option and two-thirds do two or three. Only a few able students taking six options actually get a balanced science course by doing physics, chemistry and biology and to do this requires 30 per cent of the curriculum time. Five-option students can do either physics + chemistry or chemistry + biology. The mainstream combined science course in years 4 and 5 takes 12.5 per cent of the total time available. It is interesting that the small group of ten non-examination students get 15 per cent science in their two final years, more than many of the others.

School D (Fig. 6) has a much simpler system than that of School C and, moreover, it ensures breadth and balance for nearly everybody. Science forms part of the common timetable core throughout. Comparisons with our other examples must be made with care because, whereas all the others operate a 40 period timetable, *this school has only 35 periods.* Most students do a balanced combined science course throughout the five years, albeit a course which occupies only 11 per cent of curricular time in years 4 and 5. In 1983 two groups of the most able students did physical science at this stage and all but seven of them added optional biology to produce the appropriate breadth. That so few opted out of biology might perhaps be explained in part by the fact that it is blocked against building studies, motor vehicle studies, nursing and cosmeticology, typing, childcare, art



MA = mixed ability

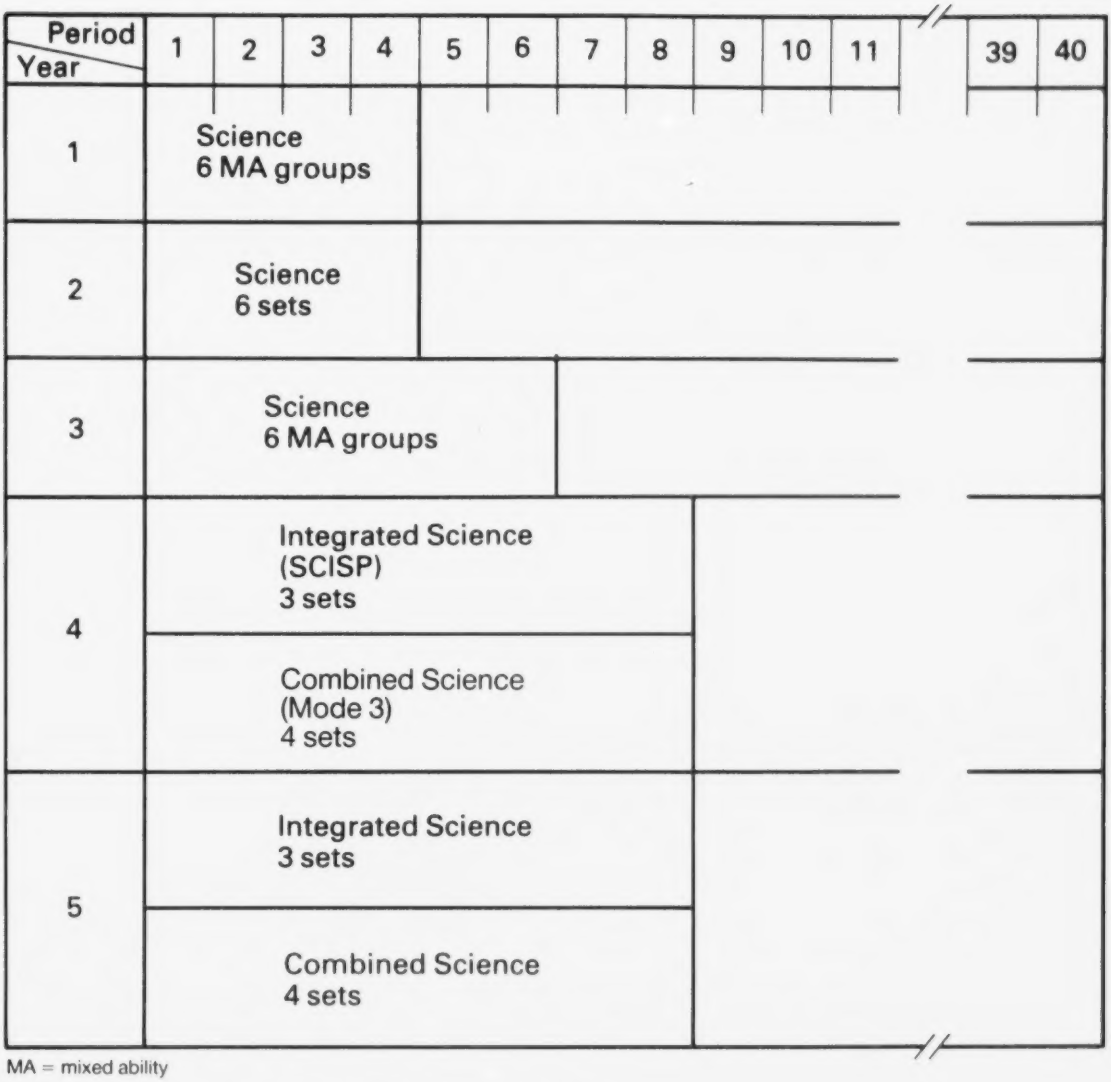
Fig. 7 *The place of science in the timetable: School E (N. Yorkshire, 1983)*

and woodwork, even the last two of which might be classified in some people's minds as 'non-academic' . . . but this is only speculation!

The simple structure means that the science department can exercise considerable autonomy and organise classes and subject matter in a very flexible way. It would meet our criteria if the mainstream combined science course were extended so as to become a 'double subject'.

In School E (Fig. 7) all the science is taught within the timetable core. It takes the pattern described in D a stage further and here all our criteria are fully satisfied. Once again the science staff, working as a team, have a wide measure of autonomy and flexibility.

The final example (School F, Fig. 8) is similar to School E but provides even fewer constraints on the science teachers. Students are setted by ability at various stages but this is the responsibility of the science department and is not imposed upon them. HMI comment in their report on School F (3.2):



MA = mixed ability

Fig. 8 *The place of science in the timetable: School F (Berkshire, 1983)*

> *Departments have been able to use the autonomy they receive over grouping pupils to make economies in the deployment of staff, particularly for practical work.*

Opportunities exist for team teaching although at the time of reporting that opportunity had not actually been grasped.

40% of the students were entered for SCISP or an associated Mode 3 CSE course and others did Mode 3 combined science (physical science + biological science). External examination results incidentally were very good!

The pattern in the first two years

The amount of time spent on science in the first year usually appears to be somewhere near our recommended time of 10 per cent although a few schools allocate rather more time. In the second year the average is about the same but there is a bigger spread. Six of the schools in our sample allocated 15 per cent or more and one of these, a grammar school, allocated 23 per cent!

In the first year, or sometimes just the first term, science is quite often taught in mixed ability groups but about half the schools are banded. Very few set or stream at this stage but setting is usually introduced quite early on and there are not many mixed ability groups left in the second year. It is usual for science lessons to be blocked together on the timetable for the first three years and so it is possible for science departments to make their own decisions about setting or

grouping the students in other ways. Team teaching is also a possibility in such a situation but rarely seems to occur.

Combined science courses are very common in these early years and sometimes integrated science. Of the schools in our sample only one timetabled physics, chemistry and biology separately in year 1, one provided physical science and biology, and, somewhat surprisingly, one taught physics and biology only, without any chemistry. In the latter case chemistry was introduced in the second year. Otherwise there was little change in the pattern in the second year. Only one more school introduced the separate subjects for everybody while another introduced them just for the more able students.

The pattern in the third year

The minority of schools that continue mixed ability teaching in science from the first into the second year still retain it in the third year.

The pattern changes markedly in two ways at this stage. Firstly there is usually, but not always, a bigger time allocation. The average time allowed is about our 15 per cent recommendation but there are wide variations both above and below this norm, from as little as 8 per cent to as much as 26 per cent. In those schools that are banded the top bands often get more science, and sometimes quite a lot more, than the others.

The other major change is towards timetabling the separate subjects. About one-third of the schools in the sample continued with combined or integrated courses for all students while six others retained it for some but provided separate sciences for the most able. A few schools did this by adopting a sort of modular system whereby the three sciences rotate from group to group, each subject being studied for a term, or perhaps half a term at a time. **In Better Science: Making it happen** (where its shortcomings are discussed) this is called a 'circus'!

The timetable structure in the third year is undoubtedly influenced by the almost ubiquitous option pattern in the following two years and by the prestige of the separate subjects. The youngsters need to know about physics, chemistry and biology and what the words mean. How otherwise can they choose their options? This influence is doubly regrettable. One of the SSCR guiding principles has been a belief in a 'bottom up' approach. For too long external examinations, especially for the more able, and other 'top down' influences have exercised a distorting effect on the rest of the curriculum. The other associated problem is that the emphasis on a three subject approach has the effect of devaluing some of the excellent integrated or combined science options that could be made available in the fourth and fifth years and which could help to provide breadth and balance at that stage.

Some schools of course take students in at this age from middle schools. There is evidence of lack of continuity in making this transition, perhaps because of ineffective assessment and reporting procedures.

The pattern in years 4 and 5

Options are the norm at this stage and as we have already seen they can distort the third year curriculum. In large schools there is often setting by ability within the option pattern and sometimes there is a different option pattern for different bands. The latter is effectively what happens at School C whose curricular structure was described above. It is usual nowadays for schools to ensure in some way that every student does at least one science subject up to the age of 16 but there are still places where this does not happen.

The more able tend to do more science or at least to have the opportunity to do so. The frequent appearance of physics, chemistry and biology as separate options perpetuates the tendency for able students to spend a disproportionate time on their science studies which leads in turn to an unbalanced overall curriculum. It is even possible to study as many as four sciences in some schools! The separate sciences, and especially physics, are often seen as being appropriate for the most able with combined science of some sort as an alternative for average and less able students.

It will be interesting to see whether the advent of GCSE changes the situation. GCSE is a very important and exciting development but there is one aspect that is worrying and perplexing. The early work on subject criteria concentrated on the traditional three separate sciences and this bias can also be seen in the titles of examination syllabuses approved by the Secondary Examinations Council. This is unfortunate because the approach is incompatible with the stated DES policy of breadth and balance within a maximum time allocation for science of 20 per cent in the two years leading up to GCSE assessment. It is to be hoped that this conflict between two formative DES initiatives will be speedily resolved. In this connection, it is encouraging that a working group has been set up by the Joint Working Party for the Review of Criteria to recommend a generic title as well as national criteria for a dual award balanced science GCSE examination which is compatible with the DES policy statement and the aims of the SSCR. Meanwhile, there are already some appropriate dual award syllabuses in existence. These include the following:

1 Science (dual award) (NEA)
2 Science (modular) (NEA)
3 Coordinated Science (Suffolk Development)

(MEG)
4 Science (Core) (MEG)
5 Additional Science (Options) (MEG).

The last two together constituted a Mode 3 submission by a group of Leicestershire schools (**3.3**).

There does seem to be a real, though probably slight, danger of chemistry being squeezed out of the curriculum. This arises not because of the introduction of two subject combinations such as physical science + biological science, which could actually help to keep the study of chemistry alive, but rather because the combination of the traditional subjects physics and biology provides spurious breadth within a reasonable time allocation. The Royal Society of Chemistry established a working group in association with SSCR which hopes to produce a report looking at the place of chemistry in the curriculum in the light of the various models that have been proposed for providing broad and balanced science. We know of one school which adopts the novel procedure of making either chemistry or integrated science compulsory. If the former is chosen then physics and biology are available within the option pattern as further studies but neither can be studied without chemistry.

A verdict on the options system

All students are individuals, differing in their ability, backgrounds and culture, their interests and their aspirations. It is therefore right that they should be given some choice about the nature of their studies; they should be enabled and encouraged to negotiate their own curriculum in at least a limited sense. One way of providing such opportunity is through an options system. It provides choice but assumes that most students will choose wisely and will not wish to change later. Lengthy and sensitive counselling might well be necessary to ensure that they exercise their choice sensibly and effectively; this can cause a great deal of stress and anxiety to staff, students and parents. It also tends, as we have already seen, to distort the third year curriculum. In practice, even after careful preparation, problems often arise because students change their minds after they have started their courses. The very complexity of the option system makes for inflexibility once choices have been made.

Coordination of studies across the different options is very complex because of the different programmes the students are following. The type of science, and perhaps the amount too, varies from one individual to another.

It will be apparent from the above remarks that we consider the traditional option system to be unsatisfactory. It does not ensure breadth and balance; indeed it militates against them. No amount of tinkering with such a model can cure its inadequacies and probably only serves to make the system more complex and unwieldy. It is possible to insist on the study of a science, perhaps by having one option block consisting entirely of science subjects, but that does not bring balance.

So what are the alternatives?

We could make a common science provision part of the timetabled core occupying about 20 per cent of the curriculum time in years 4 and 5. It does not follow from this that the three separate sciences have to disappear as school subjects. A three subject coordinated approach along the lines recommended by the Royal Society is perfectly feasible. We discuss the organisation of the subject matter further in Section 5.

Most of the schools in our sample operated some sort of option system but nine had science as part of the core timetable throughout the five years. Five of these however only had 10 per cent of curricular time allocated for compulsory science with further science provided as part of the reduced option pattern.

The recommendations we wish to make at this point are to select the *simplest* structure consistent with the school situation and aims and to remember that an option system is not the only way, nor the most effective way, of allowing choice. There only seem to be two timetabling alternatives in years 4 and 5 if all students are to experience a broad and balanced science course spread over a reasonable proportion of the total curricular time. They are:

1 Science timetabled as part of the core curriculum for about 20 per cent of the time (8 periods/40).
2 Science timetabled in the core for a shorter period (about 10 per cent) with further science within a reduced option structure.

If the second alternative is adopted then two conditions must be met:

- all students must select a further science option; and
- the various alternatives available should be designed in such a way that each of them, together with the core, provides a broad, balanced and coherent course.

We prefer the first alternative if only because of its simplicity. If it is thought necessary, the science department should be able to operate its own flexible and coordinated option structure within this block of time. One way of achieving this would be through a modular approach.

Broadly speaking we would like to retain the timetabling structure normally adopted in the first

three years but science departments should operate with greater autonomy within the blocks of time allocated to them. A reform of the timetable in years 4 and 5 should reduce the pressure for separate subject science in year 3.

Timetabling for links across the curriculum – technology as a coordinating theme

Much cross-curricular liaison, coordination and cooperation can be carried out independently of the school timetable structure and the reader is referred to chapter 5 of *Planning for Science in the Curriculum* (**0.2**). There are however ways in which the timetable can facilitate, encourage and even tacitly enjoin such activities. For many years the science education community has agonised over science and technology. We felt sure technology was 'a good thing' and that we ought to teach about it . . . but nobody really seemed clear about precisely what the word meant! Recently some deep thinking has clarified this issue. The SSCR takes the view that technology is essentially interdisciplinary (see **3.4** and **Better Science: Making it relevant to young people**). We therefore use it to exemplify the timetabling both for cross-curricular coordination and also for inter-departmental collaboration.

It is generally recognised that all students should be educated for technological awareness and technological capability. That in itself would have few if any timetable implications but we favour the Black and Harrison model (**3.5**). It is discussed in **Better Science: Making it relevant to young people** where a rationale is given for this approach. The model requires the actual timetabling of interdisciplinary time to enable students to engage in 'tasks' – problem solving and design activities supported by the 'resources' of several subject areas – and thus to develop technological capability. Fairly substantial blocks of time are desirable for this kind of work rather than isolated single periods.

Four subject areas which might make important contributions are science, craft, mathematics and English, but we wish to emphasise that collaboration between these four subject areas is not necessarily the best way to introduce an interdisciplinary approach. We use it just as an example to help us to examine some of the timetabling implications. Some schools might wish to start with other subject areas: home economics, geography and history are obvious possibilities.

Black and Harrison hint at various possible solutions but do not discuss any of them in detail. Broadly speaking there are two alternatives. The first is an occasional 'projects week', perhaps termly or annually, in which the normal timetable is abandoned and the whole school engages in this sort of work. All the staff and resources of the school are available and the whole situation is very flexible. Experienced teachers will be aware that there is also a strong potential for chaos and so very thorough planning and careful organisation are essential. It may also be felt that the gaps between such events are too long. Despite these minor criticisms we think such an arrangement would be well worthwhile and there are several schools who do this.

In the SSCR we have discussed another alternative in a little more detail (**3.4**). Four subject areas seem to have an especially important contribution to make. They are science, mathematics, CDT, and English (communications). These might be expected between them to take up about half of the total curricular time. At the very least the departments responsible for them should be liaising closely and coordinating their work at every stage throughout the school.

Could they not progress a little further and pool some of their time so that perhaps half a day a week could be devoted to task work? This would be a relatively simple thing for the timetabler to arrange provided that all four areas formed part of a common curricular core. Moreover if classes were blocked, perhaps in half-years, it should be possible for specialist staff from all the four resource areas to be present together (and specialist facilities and accommodation to be available too). The inclusion of an extra teacher as a floater would bring considerable flexibility and would facilitate the movement of staff from class to class within the blocks so as to make their individual expertise available where it is most appropriate at any particular time.

Students too would have to move from time to time to make best use of the diverse facilities. This would have to be carefully controlled but it should not present serious problems because all the specialist areas would be supervised. Obviously this sort of arrangement would involve a lot of interdepartmental cooperation and planning. If such an experiment were successful it could lead to an expansion of this interdisciplinary part of the timetable as other departments join in.

Technology is only one of several themes which cut across traditional subject boundaries. There are for example personal, social, political, economic and moral issues which also relate to both science and other curriculum areas. These are matters which the SSCR has stated ought to be explored by school students as part of their science education. Thought should be given to how to provide appropriate opportunities for students and what the time implications are. We are talking here not about a totally different approach to cross-curricular work but merely a different emphasis. We would not wish to convey the

impression that these issues are distinct from technological problems. Indeed the reverse is true because all of them, personal, social, political, economic and moral issues, and technology too, are basically human issues. This work need not necessarily all be done in lessons formally labelled 'Science' but certainly science teachers should be involved in the planning. Links need to be established with the subject areas responsible for social studies, environmental studies and the like. Health education is a cross-curricular field in which SSCR has taken a special interest (see **Better Science: Health and science education**) and it could probably subsume some of the topics and issues mentioned above. Here again joint planning is needed and probably some give and take over curriculum time, perhaps along the lines suggested.

SECTION FOUR

Designing the framework

Strategy and tactics

The first things to do in designing new science courses (as was discussed in Section 1) are to decide aims and objectives, to devise criteria to test whether the aims have been achieved and to write a rationale linking the aims and criteria. There are two other major parts of the planning process, referred to in Fig. 9 as 'Strategy' and 'Tactics'. These are probably best tackled concurrently because they should influence and interact with each other.

The strategy requires joint planning but the tactics can safely be left to individuals provided of course that they keep the rest of the team informed and react positively to criticism. We shall not have much more to say in this report about tactics because it is dealt with very fully in other SSCR **Better Science** Curriculum Guides, especially **Approaches to teaching and learning**, **Choosing content**, and **Assessing progress**. All the other guides have something important to say in this context too. Box 4 presents some of the questions that the science staff should address as part of their planning strategy.

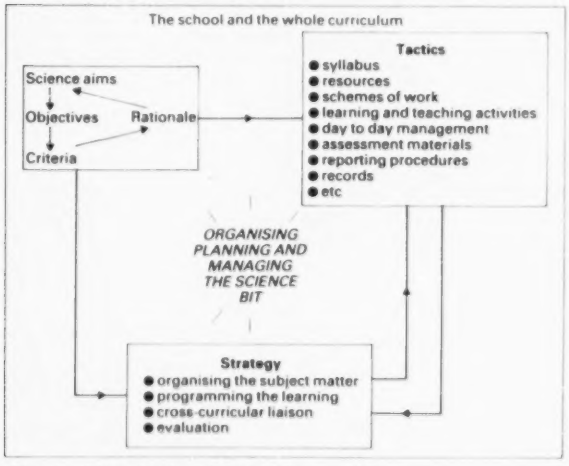


Fig. 9 The school and the whole curriculum

The first two of these questions are about how to organise the subject matter and this is discussed further in Section 5. Another important strategic decision to be made (questions 3–7) is how the learning is to be programmed. This is discussed in Section 6. All this planning, not just the obvious questions 9 and 10, should take place within the context of the whole school curriculum – hence the outer box in Fig. 9 – and therefore continuing consultation with colleagues is important.

1 Are the sciences to be taught separately and if so how will the learning be coordinated?
2 Alternatively, will we go for combined or integrated science?
3 What arrangements will be made to provide appropriate learning experiences for students of different abilities?
4 Will there be a sequential linear course or perhaps several parallel ones?
5 Alternatively, will a modular structure be adopted?
6 What general principles should we adopt in order to achieve coherence and progression? This will present different problems according to whether a linear or a modular approach is adopted.
7 How much choice should we allow? Who will be involved in making choices? When will it operate and how often? What mechanisms will be used to implement it? How will it affect coherence and progression?
8 What general principles should we adopt in formative and summative assessment and in reporting?
9 What arrangements should we make about cross-curricular liaison and what do we hope to achieve by it?
10 How can we promote effective liaison with the feeder schools and what is its purpose?
11 What mechanisms should we set up for reviewing, evaluating and developing the curriculum regularly?

Box 4 Strategic questions for science staff

A closer look at some of the factors

The remainder of this section is concerned with factors (Box 5) which need to be considered in arriving at organisational decisions.

Breadth	Differentiation
Balance	Assessment
Relevance	Continuity
Coherence	Evaluation
Progression	Development

Box 5 Organisational factors

These factors are all given prominence in *Science 5–16: A statement of policy* (**0.3**) and they are also dealt with, explicitly, or implicitly, in the other SSCR Curriculum Guides. It is important to consider

them here because they must be borne in mind when planning the curriculum and its associated organisation. The use of jargon is inevitable because we are dealing with technical aspects of curriculum organisation and we need precision in our language. One of our objectives is therefore the careful definition of the terms we use.

Breadth

There is certain amount of simple **factual information** which it is reasonable to expect science students to learn at school and it is likely to relate to a wide range of disciplines. This information should be of potential use to them either in everyday life or in facilitating further study. It is the kind of information which is constantly needed and inconvenient to be repeatedly looked up. This very use will normally ensure that it is remembered automatically without an inordinate effort. If it is forgotten that will be because it is not meeting the criterion of usefulness. We think that there needs to be a drastic reduction in the amount of factual recall that is expected of students.

Much more demanding on both teacher and learner is the need to know, to understand and to be able to apply important **concepts** covering what is referred to in *Science 5–16: A statement of policy* **(0.3)** as 'the whole range of science'. Traditionally this would have been taken to mean biology, chemistry and physics, but consideration ought also to be given to other branches of science – provided the total content is reduced. Earth science and astronomy are branches that some working groups have been exploring and readers are referred to *Arches* **(4.1)** or **Better Science: A Directory of Resources** for further details.

Courses should refer to important applications of scientific principles and their social and economic implications. This of course is related to the whole question of technological awareness and is referred to in more detail in **Better Science: Making it relevant to young people**.

Science courses should develop a range of **practical and intellectual skills and processes.** It is arguable that these have universal applicability across the whole range of science disciplines although some are more important in some subject areas than others. Students should experience the **technological process** which certainly bridges subject boundaries. This has been discussed in Section 3.

Finally, and very importantly, it should be remembered that science education should be concerned with the inculcation of certain **attitudes**.

Balance

Balance is related to breadth in that it is concerned with the proper weighting of the various components referred to above.

It is for individual schools to decide what is to be included and where appropriate to persuade examination boards to agree. The Secondary Examinations Council is insisting on parsimony of content in examination syllabuses and seems to be persuading examination boards to reduce content loading. SSCR is concerned to emphasise the need for a broad *range* of content but it is very easy with this in mind to add a lot and cut very little! If we put in some earth science and some astronomy, for example, then we must cut out something else. Indeed we need to do better than that if we are to leave more time for the development of skills and processes. One of the SSCR Central Team's early publications was *Towards the Specification of Minimum Entitlement: Brenda and friends* **(4.2)** in which we listed what we called 'the **substance** of a programme of science studies' including the necessary content, skills, processes and attitudes. It is the coverage of all these aspects that constitutes breadth. It is the careful pruning of each

branch of this curricular shrub that constitutes balance. Healthy growth cannot occur if some parts run riot while others are choked.

We think that **Better Science: Choosing content**, in making detailed recommendations about what ought to be included in the science curriculum, does manage to achieve breadth while reducing content. It addresses more rigorously the task that was started with *Brenda and friends*.

Teachers should also aim to balance the different types of stimuli and learning experiences offered to students. These are discussed in **Better Science: Approaches to teaching and learning**. In planning for balance special provision should be made for enhancing the participation of girls and for the expression of cultural diversity. (See **Better Science: For both girls and boys** and **Better Science: Working for a multicultural society**.) Schools should aim for *vertical balance* over five years as well as *horizontal balance* in any one year.

Coherence, progression and relevance

> *Coherence means that the different parts of a course should be connected in a logical and consistent way.*

It is crucial that this should be *apparent to the students*. Our main concern in this report is with the science curriculum but coherence should extend across the whole curriculum. That is one reason for liaison across subject boundaries and the need for sensitivity and responsiveness to cross-curricular links.

> *One of the most important aspects of curricular coherence is progression. By this we mean the steady increase in understanding and competence that each student should experience.*

Each stage of a course should build upon and take forward what has been done before. Unnecessary repetition should be avoided but it makes good sense to return to similar content areas at intervals, provided that the depth of understanding is enhanced each time. Moreover repeated practice of skills, preferably in different contexts, is essential if they are to be mastered. At first glance it might appear that we are talking about a highly structured and pre-ordained sequence of learning experiences but this idea should be treated with caution. Because all children are different – in their abilities, their personalities, their needs and interests – we must build flexibility and choice into our teaching schemes.

We are advocating a simplification of the school curriculum and the timetable mainly by an expansion of the core of subjects to which all students should be exposed until they are 16 and a corresponding decrease in the number and

diversity of subject options in the last two years of compulsory secondary education. This, together with a broadening and streamlining of the science curriculum, should make for greater coherence. To some extent it reduces the amount of choice available to students but there are ways of compensating for this. Course planners must find ways of allowing choice for individuals while at the same time providing coherence and ensuring appropriate progression.

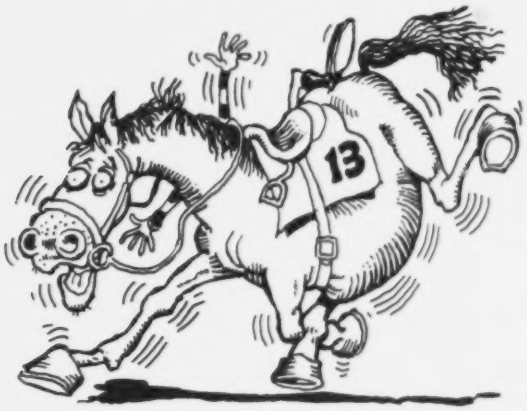
The answer lies in carefully planned formative assessment, together with counselling and negotiation. This should enable teachers to offer their students choice as they progress through their studies without their curriculum becoming unbalanced.

It is just as wrong to compel students to engage in study which they find irrelevant or boring, or to fail to cash in on their enthusiasms and interests, as it is to let them drop out of science completely. This brings us to the matter of relevance, another of the issues highlighted by DES in the policy statement (0.3). The word is used by educationalists in its everyday sense. The policy statement says

> *Science education . . . should draw on the environment and the experience of the pupils themselves.*

We fully endorse that statement but wish to qualify it. There are parts of everybody's environment and experience that they do not find particularly interesting and inspiring, parts perhaps from which they are quite keen to escape. Teachers naturally have views on what issues are relevant and topical and on what ideas and skills are likely to be valuable in the future . . . but students have strong opinions about such things too. We need to draw upon those interests and experiences that students really find exciting and motivating. Although they live in the same environment and the same community different

people's interests and enthusiasms will not always coincide. Moreover some of the experiences that interest them may be vicarious or even fantasy. Is there any reason why we should not sometimes use science fiction, for example, as a starting point for thought or discussion? We need to find out what interests our students, what will fire their imagination and their spirit of enquiry, what they think is important and relevant.



Too much breadth, not enough balance and very uncertain about progression.

We should allow individuals some choice. They should be able to select alternative topics for study. They should be given some autonomy in how they study an idea or tackle a problem. These are relatively short-term choices which can be made in a well informed way and at an appropriate time. Furthermore all is not lost if a choice turns out to be misguided. It is much easier to redeem such a situation than to pick up a new subject at a late stage because you find that a term ago – or a year ago – you selected the wrong option!

Coherence is achieved as a result of successfully combining breadth, balance and progression (Fig. 10). This is perhaps the fundamental task of the course planner.

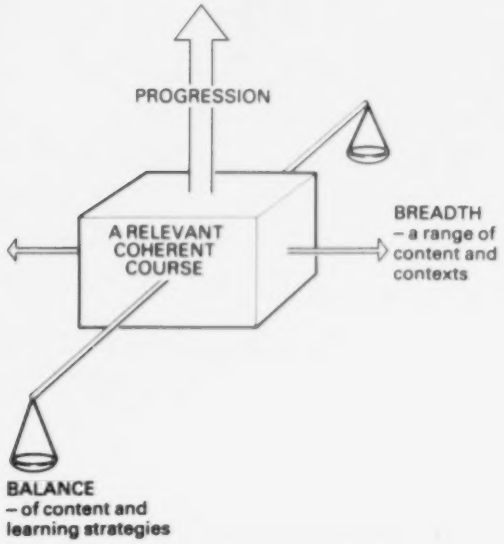

PROGRESSION
A RELEVANT COHERENT COURSE
BREADTH – a range of content and contexts
BALANCE – of content and learning strategies

Fig. 10 *Coherence: a three dimensional concept*

Differentiation and assessment

Differentiation, in the educational sense, means distinguishing between the ability and levels of achievement of different students and providing appropriate, and differing, learning experiences at each stage of their development.

Differentiation has always been an important part of a teacher's job. Many of the decisions are intuitive and will inevitably continue to be so. Intuition must however be backed up by more formal **assessment** of students' progress, good **record keeping** and regular **reporting** in a form which is accessible and useful to all interested parties.

There must be a very clear departmental policy about this. A *uniform system* of recording must be adopted so that everybody understands it and can find out relevant information about individual students without undue difficulty or delay. Information must not just be available; the system must ensure that it really is passed on effectively and reliably. The people who need this information include students themselves, their parents and other teachers. It is on this basis that decisions should be made about an individual's programme of work. The *students should be involved* in the assessment process (including some self-assessment), its interpretation and the subsequent decision making.

Assessment which has as its prime objective the reviewing of progress with a view to making decisions about future study is known as **formative assessment**. **Summative assessment**, although it may be part of a continuous assessment scheme, is intended to provide information

for reporting on a student's overall achievement at the end of a course. This of course is the information which is recorded, in some form or other, on certificates awarded by independent examining bodies. It is common for some assessments to be used both in a formative and a summative way.

Continuity

Not so very long ago it was very unusual for children to receive any significant science education before going to secondary schools. This situation is rapidly changing although there is still a wide variation of provision and practice in primary schools. The Department of Education and Science says (**0.3**, Para. 29) that every primary school ought:

> *. . . to produce a properly constructed scheme of work (in science) and to make arrangements for assessing and recording pupils' scientific competence.*

A responsibility is placed upon secondary schools too, later in the same document (Para. 32):

> *. . . they have to ensure . . . that the pupils' early start is neither ignored nor undervalued but rather reinforced and exploited in their subsequent work.*

This process of building on foundations already laid in other institutions is called **continuity**. It arises at other stages too – at the interfaces with further and higher education institutions and with employment. The existence of three-tier school organisation in some LEAs introduces further important interfaces.

While secondary schools have, with varying degress of success, traditionally liaised with **potential employers** and with **further** and **higher education**, liaison with **primary schools**, especially in the context of science education, is perhaps less well developed. There is a need for joint curricular planning to ensure that secondary schools know what is going on in their feeder primary schools and can build upon their work. Coordination between these different primary schools, nurtured and encouraged perhaps by the secondary school, also provides the opportunity for them to develop a joint policy which would make it easier to achieve continuity. These aspects are discussed in more detail in *Planning for science in the curriculum* (**0.2**). There is also an important discussion of the issues involved in the SSCR publication, *Primary Science, Secondary Science: some issues at the interface* (**4.3**). The Leicestershire SSCR 10+ Science Group (**4.4**) has also done a lot of work in this field. They made a detailed survey of what is actually happening in science education for this age group and have presented proposals for development.

There is of course another aspect of liaison which facilitates continuity. That is the **passing on and use of records** about individual children. There is more to this than a mere exchange of information between schools. In primary schools children relate closely to their own particular class teachers. When they go to secondary schools they each have several specialist teachers intimately involved with their work and progress. How is the information to be put into the hands of the individual science teachers concerned and then used constructively? A quick glance at the records of thirty children is unlikely to be of lasting value. Must each specialist teacher copy all the relevant information laboriously into a markbook? Or should everybody be given a separate copy? To think of the effective management and use of such a mass of paperwork is daunting.

This is an organisational matter which secondary schools ought to take very seriously. It must be admitted however that effective exchange and use of records between schools is more easily said than done. It is an issue which has been discussed at some length by the SSCR Curriculum Frameworks Advisory Committee. Despite the wealth of teaching and departmental management experience represented there, they were unable to provide convincing answers to this intractable problem. Perhaps secondary schools and departments should recognise the impracticability of coping with it through written records and concentrate instead on **personal liaison** with their primary colleagues, something which is urgently needed anyway. One suspects that much careful record keeping by primary schools, conscientously passed on to the secondary schools, is hardly worth the effort as far as subject departments are concerned, however useful and important it may be in terms of pastoral care. On the other hand it may be that **computerised record keeping** will result in a more effective system. Teachers

certainly should not waste precious time and energy on procedures which are ineffective.

Evaluation and development

It is extremely unlikely that a single overhaul of a school's science curriculum and organisation will get everything right and solve all the problems. Even if a nearly ideal system were to be temporarily achieved the situation would change; a school and the community it serves are living and evolving entities. The planners can therefore never rest on their laurels. They should be continually evaluating and adapting their strategies. The necessary mechanisms for doing this ought to be built into their organisational structure. These mechanisms should involve the science staff in going back at regular intervals to reassess their aims, their criteria for evaluating the success of

their aims and the rationale linking these as discussed in Section 1.

SECTION FIVE

Organisation of the subject matter

Pupils deserve to be provided with challenges and opportunities which present a coherent and consistent picture across all their work in school science (**5.1**)

The need for a common curriculum and its implications

Science departments should organise the teaching of the various subject components of their courses so as to provide breadth, balance and coherence as defined in Section 4. It is impossible to do this if the school operates, as many do, with a more or less free choice of options in years 4 and 5. A common curriculum is essential, either for the whole school or for homogeneous self-contained groups within it, such as ability bands. Although this would deny students what might be called the 'maxi-choice' of the option system there are ways of providing mini- and micro-choices within the common courses and units. This has already been mentioned in Section 4.

One of the most obvious ways of providing a coherent science curriculum is through an integrated science course. It is also quite feasible, however, to organise on the basis of separate subjects, usually three but quite often two, provided the teaching is properly coordinated. Thus there are essentially two types of solution:

1 an integrated science approach; and
2 a coordinated separate subject approach.

We look in detail at each of these alternatives later in the section and also at what might be thought of as compromise solutions – combined science and two-subject science. Whichever alternative is adopted *joint planning* involving all the teachers is necessary and also *a common system* of day to day management, pedagogy and assessment.

We can't do it because . . .

Neither of the two basic types of organisation nor their many variations should *of themselves* make inordinate demands on staffing or resources. No extra time would be required and indeed the simplification of the system might well make timetabling easier. Nevertheless it should be recognised that the implementation of a policy of science for all is bound to make extra demands if a significant number of students has previously spent less than our recommended time on science studies.

In Section 1 we mention, in addition to the largely spurious constraint of the timetable, two other possible inhibitors of change. They are tradition and insecurity. Whilst initiators of reform should be sensitive to the former they should not allow it to hinder them. Insecurity, especially of teachers, must on the other hand be taken very seriously. It is after all not unreasonable to feel insecure if one is asked to engage in radical change without being properly prepared. Under such circumstances teachers cannot be expected to give of their best. This is one very good reason for thorough consultation and joint planning with everybody concerned. Teachers will need plenty of support, especially if they are to be asked to teach outside their specialisms and have not done so before. Appropriate INSET provision should be a top priority either within school or elsewhere.

Another aspect of insecurity is the question of status. Those who have it, and have worked hard to achieve it, are often understandably unhappy when it is suggested that a system they devised and in which they have invested time, thought and effort is inadequate. Conversely more junior colleagues may be unwilling to challenge established practice either because they feel a little intimidated or maybe simply out of sensitivity for the feelings of others. We refer to this in Section 1.

Selecting an organisational model

In his 1986 Presidential Address to the ASE, from which we have already quoted (**5.1**), Paul Black says:

There are teachers who feel strongly that all the truth is to be found in one approach and none in the other, so that the future must be secured by combat with the other side.

Despite some opinions to the contrary SSCR has always adopted an open mind on whether it is

preferable to adopt an integrated or coordinated (separate subject) approach. We continue to do so and feel that each school must make its own decision in the light of its circumstances. Black's address should be read carefully by all science teachers embarking on curriculum reform. He exposes the weaknesses of some of the special pleading that has been made in the past and which has provided unsure foundations for solutions to the problem of curricular unity. He suggests five guiding principles (Box 6) which should enable us to cope with the confusion threatened by conflicting arguments.

1 A curriculum's author must specify the nature of the unity they intend if teachers are to implement that intention.
2 We must respect the differences between the different parts of science. . . . The increasing complexity as we proceed from electron to molecule to ecosystem means that in practice the sciences have had to use different concepts and different methods.
3 We should distinguish the particular concepts and methods, which have been invented by scientists to deal with restricted classes of problems, from the needs of real and messy interdisciplinary problems . . . The work on real problems should be interdisciplinary.
4 Many of the problems and potentialities of science education can only be resolved within a comprehensive view of the curriculum as a whole. . . . Technology needs a role and status in the curriculum quite different from that of established subject disciplines.
5 Whilst science teachers have to pay some attention . . . to top-down pressures, they also have a right to exert bottom-up pressures from their own perspectives.
(They) are not mere servants of the scientific culture of our society . . . in an important sense they are its guardians.

Box 6 *Five guiding principles* (Black, **5.1**)

The first principle is perhaps the one is in most danger of being ignored by busy teachers wrestling with day-to-day problems and demands. It is essential to think about the philosophy of unification underlying a school's science curriculum and this should be done in the early stages of planning when aims, criteria and rationale are being developed. Black says:

> *We must be very wary of any attempt to unify science by an ersatz philosophy that does not draw upon the views of scientists or of philosophers of science.*

He feels that issues about unification have not been properly thought through in previous national curriculum development projects, even by the Schools Council Integrated Science Project (SCISP), a scheme which otherwise he holds in high regard.

It is fashionable among educationalists to make a distinction between scientific processes and scientific concepts, a dichotomy which has its uses but which is not always helpful. Black says:

> *Those who believe that we should concentrate solely on process skills ignore the fact that their pupils will be working with concepts and models whatever they do, and that these will be guiding their deployment of process skills. We have to tackle the process development and the concept framework in coordination.*

He is doubtful about the accessibility for most children of broad universal concepts spanning a range of scientific contexts but students will be called upon to use the same processes in different subject areas. So here is a reason for close consultation and liaison between teachers. Later in his address he refers to constructivist ideas of how children learn and this relates to the work of the Children's Learning in Science Project (**5.2**). Teachers need to bear in mind that when developing scientific concepts children have to start with their own existing conceptual frameworks which may be in conflict with the ones the teacher wishes to promote. A step towards curricular unity advocated by Black is that:

> *a school science department's teaching (should) always present any one concept in the same way, using identical language, and within sequences so designed that any repetition would serve to reinforce.*

Clearly this could only be achieved by careful consultation between staff and coordination of their work, whether or not an integrated science model were adopted. The development of process skills should help children to refine and modify concepts but Black warns that in searching for curricular unity:

> *. . . we should distinguish the way that scientists work from the psychology of children's learning.*

We have already addressed (in Section 3) some of the practical issues arising from the third and fourth principles. There we suggested in effect that technological tasks might form unifying themes linking not only the different science disciplines but other subjects within the school curriculum too.

We hope that this discussion will persuade innovators that it is important not only to seek unity across the science curriculum but to articulate the unifying principles. In doing this they should respect the integrity of the various scientific disciplines and their differences.

We discuss below particular organisational models in rather more detail, starting with the two

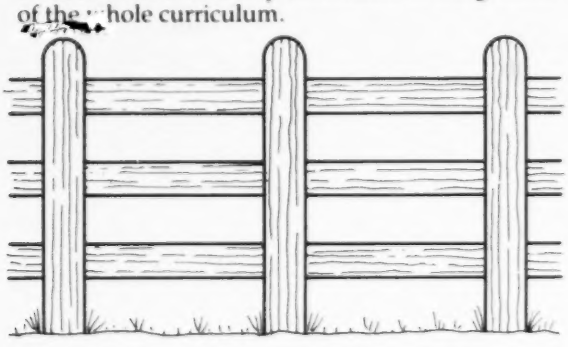
archetypal models – coordinated and integrated – and then looking at various compromises. We start with coordinated science because it is the one most closely related to the traditional separate science model, although it is fundamentally more enlightened. It is of course possible to mix the approaches over the five school years under consideration, perhaps starting with integrated or combined science during the early years and changing later to coordinated science. The basic differences between the two approaches are summarised in Box 7.

Integrated approach	Separate subject approach
Unity of method	Method depends on nature of problem
Unity of concepts	Diversity of concepts
Reductionist pilosophy: all fields are parts of the one activity	Different levels of complexity make a qualitative difference to the activity
Can confuse by artificial unifying ideology	Can confuse through lack of coordination
Real problems need distinction between different types of input	Real problems need coordination of different types of input

Box 7 *Differences between integrated and separate subject courses* (Black, **5.1**)

Coordinated science

This model was originally advocated by the Royal Society (**5.3**) as a way of achieving broad and balanced science. Biology, chemistry and physics would be taught separately but the different teachers would coordinate their work and the content of their courses so as to provide mutual support and to avoid unnecessary overlap. We might think of this model as a fence with three strong bars, each one representing one of the three separate sciences. The bars are firmly connected by strong posts. These represent the coordinating and planning actions of the teaching team and are also firmly embedded in the ground of the whole curriculum.



The recommended time allocation in years 4 and 5 was nine periods in a 40 period week. This is of course more than our recommended 20 per cent.

The coordinated science model is the least threatening solution for teachers who feel unhappy about teaching outside their specialisms and it does enable subject specialists to draw upon their strengths and expertise. Provided that coordination is planned and effectively implemented it represents a great improvement on the options system. The process of coordination, involving teachers as it inevitably will in consultation and joint planning, will introduce an element of staff development.

The model however also has a number of disadvantages. Firstly it could create timetabling problems. It places more constraints on the timetabler than other more integrated models. Perhaps more importantly it does require an extra period. This may not appear significant to people not deeply involved in school organisation but those who are will appreciate that it would reduce flexibility elsewhere and might well affect the overall balance of the curriculum. It should also be remembered that the 40 period week is not standard and the Royal Society model could be even more problematic from an administrative point of view if a 35 period week, for example, were in operation.

Second, it would provide a very limited, and some would say inadequate, time for students to be with particular teachers. They would probably only meet once or twice a week. If they did meet twice, one of the two occasions would be rather short, probably too short, for example, for useful practical work. The latter is an important consideration if, as we recommend, emphasis is placed on teaching strategies which demand active learning.

Third, despite the value of increased teacher consultation to which we have already alluded, this is the alternative which least encourages the broadening of teachers' perspectives.

Fourth, the Royal Society model does seem to perpetuate a narrow preoccupation with 'the three sciences'. It makes no overt provision for other content areas such as earth science or astronomy nor does it allow for the sort of approach to technological problem solving that we discuss in Section 3. Moreover the original proposals were concerned almost exclusively with considerations of content in its narrowest sense, reducing overlap in the interest of increased efficiency. We think this view of the curriculum and of pedagogy is somewhat naive. Since the original report was published in 1982 the Royal Society has cooperated with the science institutes in syllabus writing. There now seems to be greater awareness of the importance of process in science.

There are two ways in which these disadvantages could be removed or ameliorated. The first is to

adopt a two-subject rather than a three-subject approach and we discuss this later in the section. The other is to use a modular structure. The latter is the solution adopted by the SSCR group in Suffolk (**5.4**) and this is the course that we would offer as an exemplar of the coordinated science model. The Midland Examining Group will be offering GCSE certification based on this syllabus and it will be referred to as 'Science (Suffolk)'. In Section 6 we look at modular structures as a way of programming the learning.

Integrated science

An integrated model is likely to provide the maximum coherence but will also make the heaviest demands on teachers. In integrated science courses the learning experiences are structured to emphasise the unity of science and the interrelationships between the subjects. If we think of coordinated science as a fence then integrated science is more like a strong hedge. It has strong and separate roots but its branches are so interlaced that it is difficult to distinguish their separate origins.

It is not normally possible to label any particular lesson or unit in separate subject terms. Thus teachers new to the model have to contend not only with a general, and probably quite radical change in approach but more specifically with the fact that they will rarely be dealing with work related mainly to their own subject specialism.

The need for science departments to agree about and to specify the unifying principles underlying their curriculum has already been stressed. Because of its radical nature this is especially important when it is intended to introduce integrated science. The rationale must be thoroughly understood by all the science staff and have their full support. They will have decided that such an approach will lead to a more enriched learning environment than a route that takes them through, for example, coordinated science. Because it emphasises unity and progression it has been suggested that a spiral structure of programming the learning (see Section 6) might be particularly appropriate for an integrated science course.

So what basis for unification is most appropriate for an integrated science course? Curriculum reform in the past has often focused on content as the prime target for change. We think that to concentrate on this aspect would be wrong because there are more pressing concerns. A course integrated on the basis of content is likely to be some form of combined science. The use of process as an integrating theme might be considered but as we have already seen process should not and cannot be divorced from concepts. However many science processes are common to the separate sciences although the emphasis on them varies. The treatment of a minority, e.g. controlling variables and the notion of a 'controlled experiment', is quite different in say physics and biology.

Integration using themes or contexts is relatively easy. *Nuffield Secondary Science* (**5.5**) provided an excellent example of a thematic approach. Some curriculum reformers have suggested that 'key concepts' and 'ideas' can be considered as organising themes (**5.6**). Contexts are wider in nature than themes, but while both are likely to provide relevance they can be limiting in scope. We discuss this further in Section 7. The work of the Assessment of Performance Unit (**5.7**) suggests that contextual learning is not readily transferred from one context to another. Taken together concepts, processes and contexts can form a framework in which effective learning takes place but such a statement is probably too loose as it stands to be described as a unifying principle.

Philosophical rationales based on the essential unity of science itself can be devised. Many of the greatest scientists in the past have refused to be constrained by artificial subject boundaries . . . surely it is naive to suggest that the average youngster can emulate them! But integrated science perhaps lends itself better than other approaches to the consideration of social, moral, political and historical issues in science and the unifying principles may lie there (**5.8**).

The above discussion is intentionally inconclusive, even a little sceptical, because outsiders cannot provide the answers. The essential point is that science departments contemplating the adoption of integrated science must devise their own rationale. If they cannot do this they should probably abandon the idea of Integrated Science as an alternative altogether, at least for the time being, but that of course does not mean that they should abandon the idea of balanced science for all!

An appropriate means of **summative assessment** will be necessary, as will a suitable GCSE syllabus. Schools may decide to submit their own Mode 3 proposals. Alternatively they may consider adopting one of the following:

1 Southern Examining Group Integrated Science (SEG)
2 Northern Examining Association Science (modular) (NEA)

3 Northern Examining Association Science (dual) (NEA)
4 Hertfordshire Integrated Science Project.

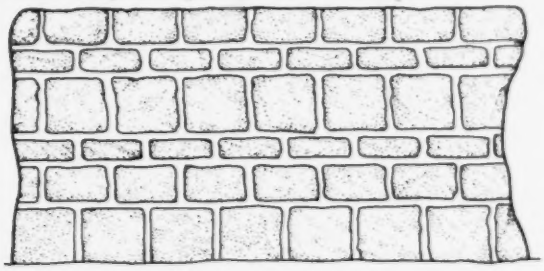
Box 8 lists the issues which, in summary, we think should be addressed and could provide an outline planning agenda.

1 Philosophy and ideology underpinning the course
2 Working definition of integrated science
3 Integrating principles adopted (with explanations)
4 Learning theory adopted
5 Learning and teaching strategies
6 Content, processes and contexts
7 Teaching skills required
8 Provision for children with special needs
9 INSET policy
10 Sources of help and other resources
11 Cross-curricular links and liaison with industry and commerce
12 Assessment, reporting and examining
13 Evaluation of the teaching and learning

***Box 8** Issues central to the planning of integrated science*

Combined science

In combined science courses the subject components by and large retain their separate identities although they should be mutually supportive. It is like a stone wall whose individual stones are easily distinguished. They represent the different topics. It will usually be quite obvious that a particular topic or lesson relates mainly or exclusively to a specific science discipline.

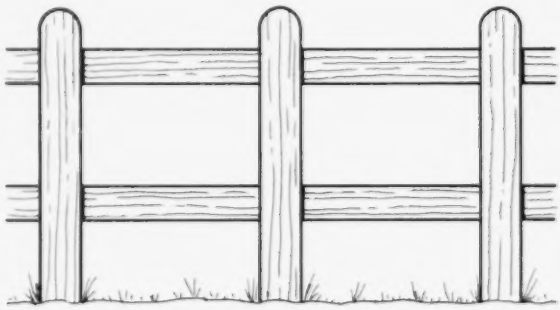


Subject specialists may not find the approach as threatening as full-blooded integrated science. Units might well be planned and organised by specialists even though non-specialists also teach them. Thus teachers can still play to their strengths and seek help from other easily identified colleagues when they need advice about teaching other specialisms. As with all balanced science courses there must be unifying principles although they are perhaps not quite as crucial here as with integrated science. A similar agenda for planning and action will be appropriate.

Two-subject science

We use this term here to indicate two subject combinations such as 'physical science' with 'environmental and life science'. The former could include physics, some chemistry and perhaps some aspects of astronomy. The latter would include biology, more chemistry and earth sciences. We are not aware of any GCSE submissions along these lines, although the thinking of some SSCR local working groups, the Leicestershire Physical and Life Science group for example (**3.3**), probably started with this model in mind. The Leicestershire group has now negotiated with MEG two Mode 3 syllabuses entitled Science (Core) and Further Science (Options). In theory students could be entered for only the first of these but this would conflict with the tenet of 20 per cent science for all held by both the originating working group and SSCR. In practice the schools associated with the group are likely to enter their students for both assessments.

The paucity of obviously relevant GCSE submissions need not necessarily deter schools from organising the subject matter along these lines for teaching purposes. They could of course submit their own Mode 3 proposals. Alternatively, they could enter students for coordinated, combined or integrated subjects or even, provided they where not liable to be overwhelmed by excessive content loading, for the separate sciences.



As we have already suggested in Section 4 a two-subject structure, if sensibly organised, could provide an opportunity and a challenge for chemistry teachers rather than a threat. It is a step towards integrated or combined science and does not suffer from some of the disadvantages of three-subject coordinated science. Timetabling would be easier in the fourth and fifth years. An appropriate time allocation for each of the two subjects would be four periods out of a 40 period week, thus corresponding exactly with our 20 per cent recommendation. This would also provide a more realistic contact time for individual teachers.

It moves away from the narrow pre-occupation with the separate sciences which characterises the Royal Society proposals and in so doing should broaden teachers' perspectives without being quite as demanding, and perhaps threatening, as a fully integrated model.

The degree of integration within each of the two broad subject areas can of course vary. A physical science course, for example, may have the physics and chemistry components essentially integrated and could then be described as a united course. On the other hand a 'physics-with-chemistry' course in which the two components largely retain their separate identity is an associated course. The latter seems to us to have little to recommend it. It devalues both physics and chemistry. Both the united approach and the three-subject coordinated approach described earlier are preferable by far.

Interdisciplinary science

For completeness this ought to be mentioned in this section although it is dealt with more fully elsewhere, notably in Section 3. We wish to emphasise that interdisciplinary approaches do not necessarily involve the disappearance of all subject boundaries.

What GCSE mode 1 syllabuses are available?

At the time of writing we know of the following double science (20 per cent) submissions that have been approved by SEC. All the boards in England and Wales have made submissions but none have come from Northern Ireland. Inclusion in the list (Box 9) should not be taken to imply that SSCR necessarily recommends them. SSCR intends that one of its Phase 3 priorities should be to look in some depth at GCSE assessment of 20 per cent science courses.

There are also mixed subject modular assessment schemes including the one offered by the Midland Examining Group (MEG). A double science award could be obtained under this scheme by candidates who offered eight or more science modules out of a total of ten.

Schools may also wish to consider certification through staged assessment or graded tests. A number of groups are developing schemes and these include the following:

1 MEG Project on Assessment of Graded Objectives (AGRO)
2 LEAG Graded Assessment in Science Project (GASP)
3 NEA Northern Partnership for Records of Achievement (NPRA)
4 Oxford Certificate of Educational Attainment (OCEA).

Examining board or group	Title(s)	Type
LEAG	Science (BCP)	Coordinated
LEAG	Science (M)	Combined (modular)
LEAG	Science (N)	Combined/ integrated (Nuffield)
MEG	Combined science	Combined
MEG	Science A + Science B	Combined/ integrated
MEG	Science (Suffolk)	Coordinated (modular)
NEA	Science (dual)	Integrated
NEA	Science (modular)	Combined/ integrated
SEG	Integrated science	Integrated
WJB	Science	Combined

Box 9 *Available GCSE Mode 1 courses*

SECTION SIX

Programming the learning – linear or modular courses?

Broadly speaking there are, as the title of this section suggests, two ways of programming learning. We shall deal first with the more conventional linear courses and then turn to modular courses. Each approach has its advantages and disadvantages, its strengths and weaknesses, and we do not wish to advocate either one as being fundamentally better than the other. Much will depend upon the circumstances of particular schools and the interests, skills and predilections of their staff. We discuss the modular approach at rather greater length only because we think it will be less familiar to many teachers.

Linear courses

In a linear course students work through a menu of topics in a predetermined way. Sequencing, progression and coherence are important and also fairly easily achieved. Provided the syllabus describes the course adequately, different teachers can conduct it in essentially the same pattern and a change of teacher need have no serious adverse effects on a class from the point of view of course administration. Of course there may well be other more personal effects of a change of teacher because the relationship between a teacher and a student can and should be a very close and sensitive one.

Unfortunately linear courses have in the past often been described merely by a list of content in the required sequence. *Planning for science in the curriculum* (**0.2**) points out the inadequacy of this and suggests some possible remedies.

> *There is a danger that (linear courses) might leave the learning of skills and processes to chance. To avoid this the teacher could have a list of behavioural objectives . . . (and note) when a student has mastered a particular objective.*

Planning for science in the curriculum goes on to suggest that an alternative might be 'to write the syllabus in terms of learning experiences'. The syllabus would then in effect become a detailed work scheme, describing the whole sequence of lessons – the activities the students would actually engage in. There is some merit in this but it could become both tedious and inflexible if it were done in advance for a whole course. It is something that individual teachers should do as part of their lesson planning in the relatively short term. If, as we recommend, students undertake open-ended tasks and active learning it is not possible to predict in detail how long an activity will take, its precise outcomes, its influence on the activities that follow and their sequence. But courses become correspondingly more inflexible as more course detail is prescribed in advance. This inflexibility can be counteracted to some extent by alternative routes or branching to cater for students' individual needs. Additional back-up activities can also be provided to give extra practice in skills where necessary, provided that the time schedule is not too tight.

Teachers should try to keep lessons and courses as *flexible* as possible and react positively to students' responses. At the same time they have to manage the work so as to cover the prescribed content and to move towards their agreed objectives. An effective compromise is most likely to be achieved if the departmental teaching team consult frequently and share their expertise. Linear courses are entirely compatible with a co-ordinated approach to subject organisation whereas it is difficult to see how a system of separate modular courses could be effectively coordinated at all.

A taxonomy of content

However a course is organised or programmed we think that it is crucial to keep prescribed content to a minimum. For detailed suggestions about what we think ought to be included the reader is referred to **Better Science: Choosing content**. Plenty of time must be available for project work, problem solving and investigations. These may of course involve extra content that has not been prescribed in advance. Avoidance of content overload is also important if students are to internalise their learning effectively and to engage in self-monitoring. In the coming section on modular courses we mention a meeting in Eccles between representatives of SSCR and the examinations boards. A working group at that meeting devised the following taxonomy of content (Box 10). It was devised with modular courses in mind but is equally valid and relevant for linear courses. Each item of content should meet at least one of the criteria.

1 It provides a medium for the learning of skills and processes

2 It demonstrates and helps students to absorb important concepts and scientific ideas

3 It poses problems for the students in such a way as to enable differentiation

4 The knowledge has inherent importance

5 The knowledge has inherent interest and is therefore motivating

Box 10 *A taxonomy of content: the criteria*

A spiral model

This is really a more sophisticated version of the linear model and was proposed by Jerome Bruner. It involves revisiting content areas from time to time as students mature and become able to cope with a more rigorous approach. It enables them to apply previously learned ideas to new situations. It allows repeated practice of skills and processes too, usually in new contexts. This can also be done in a modular structure but not quite as easily. In short a spiral course is planned so as to achieve good progression.

Modular courses

There is a tendency in some quarters to believe that modular courses can provide the answers to all our organisational and curricular ills and worries. Such attitudes are almost certainly over-optimistic. A modular structure does not guarantee any automatic improvement in the quality of learning, nor is it intrinsically progressive. It is no more difficult to perpetrate boring, uninspired, irrelevant teaching in this situation than in any other. A modular course, like a linear course, is only as good as the teaching and learning experiences and sequence that it contains. However, well-designed and well-managed modular structures do allow considerable flexibility and choice while enabling teachers to play to their strengths and special interests to some extent. Modular structures, not only in science, have occasioned a lot of interest in recent years. It was for example one of the most popular issues that SSCR working groups wanted to tackle when they were getting started in 1983. The interest probably reflected a hope that modules might solve some of the problems of our overcrowded and incoherent curriculum.

We have encouraged and organised considerable discussion about the modular approach with the purpose of articulating an SSCR view. We see it as a useful administrative device. Much thought and planning is required if it is to be used effectively in the management of learning. Two events deserve special mention. The first was an SSCR invited conference of representatives of local working groups held at the University of Leeds in the summer of 1985. The second was a meeting between SSCR and Examination Board representatives at the offices of the North Western Regional Examinations Board in Eccles the following autumn. At the latter meeting a group of delegates spent several hours in detailed discussion about modular science courses using as an exemplar the Wigan TVEI scheme which was developed by an SSCR group (*Developing a broad range of science modules*). This group has since joined forces with two Cumbria groups (*Modular science* and *Implementation of LEA policy*) to produce the NEA GCSE syllabus, Science (modular).

Well designed modular courses have three major strengths which are as follows:

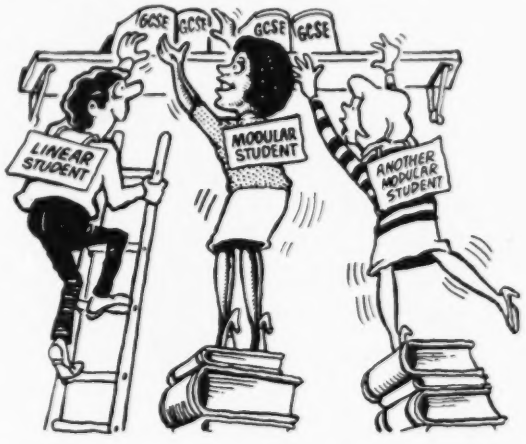
- modules provide short-term feedback and a sense of achievement to students;
- regular and rapid assessment also provide good feedback to teachers which should enable them to plan for differentiation;
- modular courses may develop cooperative teamwork, a common rationale and vocabulary while at the same time allowing individuals to use their strengths constructively.

The teacher should aim for a balance between teamwork and individual initiative.

These very strengths can lead to a possible disadvantage of modular courses. The frequent assessment and feedback and the differentiated content and approach could appear divisive in classes with a wide ability range.

What do we mean by 'modular'?

We define modules as discrete, but not necessarily interdependent, packages of learning experiences



with specific time allocations. Modules need not all be the same length but each should occupy

some simple multiple of a standard time unit (three weeks, half a term or whatever) so that they can be neatly stacked end-on and side-by-side. Tight and relatively short-term time schedules might suggest inflexibility but there are ways of counteracting this danger which we discuss later in the section. At the Eccles meeting a set of criteria for modular courses were formulated (Box 11). They apply equally of course to linear courses.

1 The individual student should be central to the learning process
2 The course should link with and build out towards other subjects
3 It should include genuine opportunities for student choice
4 Formative assessment together with counselling should enable the student to make sensible and informed choices
5 Continuous assessment is essential both to enable the choice-making process and to provide differentiation
6 Strategies should be developed to provide opportunities for problem solving and investigative work and to assess them

Box 11 *Criteria for modular courses*

Similar views were expressed, although less formally, at the Leeds conference and so these criteria seem to represent an SSCR viewpoint. We feel, incidentally, that the Wigan scheme, and therefore the NEA syllabus, meet the criteria.

Achieving flexibility

Flexibility can in fact arise in three ways, all of which require sensitive planning and management. Firstly, it is essential that considerable flexibility is built into the individual modules. Of course it is not possible to forecast accurately in advance how long a class or individual will take to master a concept or skill. So there will need to be some time available to allow work to be repeated or tackled in an alternative way. Equally important is that there should be high quality extension work available to occupy, in a productive way, those who do not require this extra time. By this we emphatically do *not* mean 'more of the same'! If the work is individualised and resource-based then it is of course quite possible for individuals to work at different paces, to take different routes, to study at differing depth, and to use alternative exemplar material. Moreover effective monitoring by the teacher should enable continuous replanning of detailed schedules of students' work in the light of their progress and developing interests.

The second way of achieving flexibility is by imaginative deployment of teacher resources and the third way is to build into the system an element of choice between modules. We shall return to both these points later in this section.

Achieving coherence, continuity and progression

A potential danger with modular courses is lack of coherence. Careful thought must be given to achieving the overall aims and objectives of the course, to progression and continuity, all of which require a holistic overview. There needs to be a clear and precise statement of essential content including the concepts and processes that are intended to be mastered. This statement is the syllabus. There should also be agreement within the departmental teaching team about the attitudes and values the course is intended to foster, whether or not these are formally and explicitly stated in the syllabus.

The achievement of coherence becomes more and more difficult as the amount of choice built into the course for either teachers or students increases. We consider that an element of choice should be an intrinsic part of a modular system but this is by no means a universal view. Choice of optional modules can be provided and also alternative routes through the work. In addition, as we have already mentioned, a good module should have a substantial element of choice within it – but this is less likely to cause incoherence. Some system must be designed to ensure that, while choice and flexibility are maintained, all students get appropriate learning experiences in a sensible and effective sequence and can progress as they mature and develop intellectually and emotionally. Proper formative assessment of progress is therefore essential.

Decisions have to be made about whether any modules should be compulsory, what constraints need to be placed on sequence (perhaps some modules may be compulsory prerequisites for others), and whether choice should be limited in other ways – by insisting for example that modules be listed in option blocks with a certain number being selected from each block. How much of the choice should rest with individual students and how much with the teacher? To what extent should students negotiate their own curriculum?

Examples of modular courses

The NEA Science (Modular) course includes a **core** of four **compulsory modules**. They are:

- Materials and their uses
- Humans as organisms
- The environment
- Energy.

Schools are advised to cover this part of the syllabus first. There is a wide **range of optional**

modules from which ten have to be chosen for the double award. There is no restriction on choice but for the purpose of providing titles for certification which reflect the emphasis in the options selected the NEA syllabus groups the modules into five types as follows:

- Biological
- Physical
- Environmental
- Rural
- Technological.

Among their ten options candidates may offer up to three approved modules devised by the school to meet their special requirements. The originators of the course feel that there should be no restriction of choice, apart from the requirement to study the four core modules, but agree that the *sequence is important* in order to ensure a development of understanding. Their solution was well-planned formative assessment and reporting followed by sensitive counselling and negotiation. We wish to emphasise the importance of **counselling**. It is important in any curriculum structure but *essential* in modular courses. We think it can usefully be combined with self-assessment which is a feature of the AGRO scheme mentioned later.

A potential difficulty with all modular courses where students negotiate their routes is that of ensuring that the prescribed content and processes are covered. Should all the prescribed content be in the core or is some of it contained in the options? To some extent the content may be determined by the skills and processes that students are expected to learn. Ideally each module should provide opportunities for students to develop *all* the required skills but this is of course a counsel of perfection. Even if such opportunities could be provided students could not be expected to learn them all in one go! Skills and processes require repeated practice, preferably in different contexts which the different modules could provide.

It is appropriate at this point to acknowledge the formative thinking and development that has taken place in Scotland in the wake of the Munn (**6.1**) and Dunning (**6.2**) reports and subsequent publications by the Scottish Education Department (**6.3**). Many of the ideas that have contributed to the development of modular courses in other parts of Great Britain were stimulated by the Scottish programme. Furthermore the assessment techniques, notably TAPS (Techniques for the Application of Practical Skills) (**6.4**), have found interest and favour south of the border.

There has been much interest in recent years in staged criterion-referenced assessment schemes. One of these, the Project on Assessment by Graded Objectives (AGRO), is developing its science proposals along modular lines (**6.5**). This is a MEG initiative but SSCR people have been involved in both development work and evaluation. Here again a core + options pattern is proposed and the core modules are:

- Matter and Forces
- Energy
- Earth Science
- Life Processes and Health.

Several optional modules and sub-modules have also been prepared and again it is intended that schools should be able to submit their own modules for approval. Unlike the NEA course the AGRO proposal is still under development but schools contemplating the adoption of a modular course would be well advised to study the material that has been developed so far and which is currently being trialled.

We have already mentioned (in Section 5) Suffolk Science (**5.4**) which is a modular course developed as a county-wide initiative coordinated by seconded teachers and advisers using the SSCR, higher education institutions and examination boards as supporters and enablers. Much of the SSCR development work in Essex also has a modular basis and the Leicestershire publication *Science For All: Ways of getting there* (**6.6**) includes a case study on Modular Applied Science at Beaumont Leys School and some general advice on the organisation of modular courses. Examples of GCSE courses are listed at the end of Section 5. There are also numerous GCSE Mode 3 submissions. Moreover it is worth pointing out that virtually any syllabus can be taught using a modular approach because the latter is concerned essentially with organising and programming the learning and not with content as such.

Many SSCR local working groups have set out to design individual modules on particular topics. These are too numerous to mention here but the reader is referred to **Better Science: A directory of resources** (**4.2**) or *Arches* (**4.1**) for further details. Another fertile source of modules is the SATIS material (**6.7**).

One of the liberating features of a modular course is that modules can be replaced without having to restructure the whole course and further optional modules can be added at any time according to the interests of individual teachers. The character of a course can thus be changed gradually to give more breadth, for example, to increase the degree of integration or to extend the choice available.

The *Salters' Chemistry Project* (**6.8**) deserves a mention at this point. Strictly speaking it does not meet SSCR criteria because it leads to a single subject GCSE in chemistry. Nevertheless, because it is modular, units could be selected from it to contribute to a combined science course. Moreover many of the modules contain material

which is often associated with physics or biology courses.

Types of module and differentiation

There are different types of module. They can be organised for example in terms of topics or subject disciplines. Topics can be integrated, interdisciplinary, multidisciplinary or confined to a particular subject area. Much will depend upon the philosophy of the teaching team and the expertise and interests of individuals within it.

Themes do not seem to us to be appropriate frameworks for individual modules. They are better seen as unifying and integrating agents across the modular structure. There are attractions in a subject-based approach which some see as a step towards a more fully integrated structure. If teachers feel insecure about teaching outside their specialisms they can move from class to class at the appropriate time intervals to teach their own modules. Another way of utilising expertise is by asking individuals to take charge of particular modules as writers, editors, organisers, assessors, consultants and advisers. Non-specialists could then stay with their own particular class throughout the course or an academic year but use teaching and learning materials prepared and organised by colleagues. In this way individual teachers can broaden their expertise without being too exposed in unfamiliar contexts. Such a system also has the added advantage of spreading the workload within the department. Readers are referred to an interesting evaluation of *Nuffield 13–16* which touches on some of the points mentioned above (**6.9**).

Whatever type, or mixture of types, of modules a department adopts, it is important to recognise that each module provides a **context** which can be clearly recognised and understood by every student. A technique which worked effectively for the compiler of this guide was to provide 'Introduction and Assignment Sheets'. These were short and attractively produced. They provided an introduction and background to the module, illustrated by drawings or photographs, and a tabulated outline of the scheme of work. They were used not only to help students to plan and pace their work but also to choose or negotiate modules. The context must be effectively communicated to the students in some way because it is important in providing motivation, purpose and a sense of relevance. It gives security, a framework for the learning activities, and as such enables students to cope with the challenges of the work and to avoid boredom.

The Eccles meeting tackled the thorny problem of differentiation and decided that it could not be solved by terminal written papers. Continuous assessment is essential and should be formative. It should lead to the negotiation of explicit work contracts by teachers and learners. Differentiation is more to do with the quality of learning than its quantity. Project work and investigations, preferably initiated by the student, may well provide differentiation. Experience in Wigan showed that the more able do more investigations and that they are able to formulate and structure them with relatively little support. They develop independence and autonomy within a common curricular framework with other students. They engage naturally and voluntarily in high level skills such as inferring and selecting appropriate procedures.

Can we then differentiate by self-selection? Is differentiation by provision or by assessment? This suggests a classification of modules based upon the opportunities they provide for differentiation. One type might start from a restricted base but enable diverse extensions, complexities and depth of study, thus providing opportunities for all levels of ability. Another more restricted type could be based on problem solving. If this type of structure were to be adopted there should probably be greater emphasis on the more extended type toward the end of the course which would make differentiation and assessment easier.

Organisation

A modular system can be made more flexible by imaginative deployment of teachers and we have already hinted at the advantages of teamwork. Team teaching is only possible if science is blocked on the timetable. It is not always organisationally feasible to block a whole year group together but many schools do operate half-year blocks. This can be a strain on resources if each class within the block is doing the same work at the same time but a modular system allows the work to be staggered. Even if the decision is made to keep each class with the same class teacher throughout, there is room in a blocked structure for some limited movement of teachers, 'bringing in the expert' for example.

The inclusion of a floater in the team increases the flexibility enormously, although of course that luxury may have to be paid for by slightly larger classes. Floaters allow increased teacher mobility and more flexible deployment. Two teachers can work together from time to time because the floater can cover one of their classes. Floaters can also be assigned to small groups or individuals where necessary or release somebody else to help with this sort of work.

Modular courses, like other organisational structures, can be based on individualised learning strategies backed up by extensive, well-designed and well-organised resource centres. This is particularly desirable, probably essential, when working with mixed ability groups.

Towards a modular curriculum

This section would be incomplete without some mention of the possibility of an extensive modular structure across the whole curriculum. As well as modules based on traditional subject areas there could be interdisciplinary modules. These might provide an attractive way of incorporating a technological approach within the curriculum, an alternative to the model suggested in Section 3. Readers are referred to a forthcoming SCDC publication on modular approaches to the secondary curriculum (**6.10**). Several LEAs including Coventry, Clwyd, Gateshead, Leicestershire, Oxfordshire and Somerset, are developing modular approaches. At the risk of being invidious we describe the thinking in one of these authorities.

Coventry LEA is very interested in a modular approach to the whole curriculum (**6.11**) and recognises a number of needs which a modular curriculum could both demand and meet. They are:

- recognising children as active learners;
- a negotiated curriculum;
- fostering a positive self-image;
- recognising the child (or mature student) as an individual;
- the command by teachers of new techniques;
- teachers to act as learning counsellors and therapists.

Coventry is still not very far along the road to a modular curriculum but that is the direction they are taking. In May 1986 a conference was held at which advisers and teachers presented a progress report and their vision of the future. They have established a teacher-based curriculum development programme with classroom trials and associated INSET. The system of working groups is similar to the SSCR model. At this stage the development work is mainly subject-based, the curriculum areas concerned being humanities, mathematics, science and TVEI.

In his introductory address to the conference Gareth Newman, one of Coventry's Chief Advisers, talked about a move away from the traditional subject-based timetable in secondary schools and predicted a number of developments (Box 12), all of which he felt were positive and advantageous.

There would be two essential prerequisites for such a revolution. There would have to be a fundamental rethink of the school day and an imaginative and progressive retraining programme for teachers.

At the end of the day A.P. Sanday, the Chief Inspector, presented a paper (**6.12**) in which he addressed the four issues of constructing a non-subject-bounded curriculum, of winning over parents, employers and higher education, of differentiation and of pedagogic method. On the last issue he took a stance which is closely related to that of SSCR and CLIS, advocating a student-centred approach which he said:

> *. . . starts from where the individual student is – and first the teacher has to find out where that is. The function of the teacher is then to help the students broaden their first-hand experience and use the tool of language to discover insights and generalisations which are useful to them in understanding and 'operating' the world in which they live. To this extent, it is the student who defines knowledge, not the teacher, and the teacher must accept partial understandings without hurrying the students on to 'correct' (examination-defined) answers.*

And this takes us into interesting areas of thought which are the province of other SSCR Curriculum Guides, but not this one.

1. Changes in teaching style would be inevitable
2. Shorter term goals would be the norm and this would encourage motivation
3. Renegotiation would heighten student and parent awareness
4. Students would be able to use modules in many different ways
5. Course location would be more flexible, e.g. technical colleges, workplaces, community centres, evening classes as well as schools
6. Students would be able to decide when or if they wish to seek accreditation
7. Modules could easily be studied by members of the community
8. Modular courses would have value in their own right, not purely as examination courses
9. Teachers would be able to plan and evaluate their work more easily and more rapidly
10. The introduction of a modular structure would influence the approach to the whole curriculum

Box 12 *Some predicted developments* (Gareth Newman, Coventry Education Authority)

A caveat

We wish to stress again that in our view a modular structure is basically an organisational framework. It *may* enhance the quality of learning but there is no guarantee that it will do so. Many of the advantages which are sometimes claimed to attach to modular courses could equally well be incorporated in linear structures. Flexibility for example is *not necessarily* the hallmark of a modular course, despite the scope for choice, if breadth and balance are to be achieved. We repeat our earlier statement that the amount of space we have devoted to modular schemes in this section stems from their novelty and the interest engendered by them and not from any innate superiority we atttribute to them.

SECTION SEVEN

Contexts for science learning

In our introduction we described contexts as the stage sets upon which the curricular drama is enacted. These contexts are sometimes selected from the theoretical structure of the pure sciences. This is not necessarily appropriate for the majority of students. Few children are destined to become professional or academic scientists. Some feel intimidated or excluded by the mystique of modern science. Others simply feel that, in the way it is often presented in schools, it is not relevant to the lives they expect to lead.

If we insist that all students should continue to study science up to the age of at least sixteen it becomes more rather than less important that they should be interested and motivated. Compulsion does not ensure enthusiasm. It is intolerable, and indeed a recipe for disaster, to compel young people to engage in a study and an activity from which they feel alienated. At least under the present system they can sometimes escape by opting out! While the traditional context of pure science may continue to be appropriate for some students, especially if it is presented in a topical way, it is reasonable to ask teachers to pause and wonder whether there might not be alternatives which would catch and hold young people's interest more effectively.

So what alternative contexts might be used? The DES paper on the National Criteria for GCSE Science (**0.1**) refers to what it calls 'directed' courses as those which 'while built from a multi-component core as a base develop one or more particular areas of interest – possibly of an applied, technical or vocational nature.' These 'areas of interest' are contexts. They must not be too restricted or they fail the test of being 'built from a multi-component core'. Environmental science and rural science, and perhaps materials science, are examples of possible course titles whereas microelectronics *on its own* would be far too specialised.

Communications, health, history and archaeology, and industry are other topics which have caught the interest of SSCR local working groups and might provide appropriate contexts either for whole courses or for modules (**4.1**, **7.1**). Most of them can also provide springboards for technological activities and valuable links with other school subjects.

The GCSE course 'Science, Technology and Society', to be examined by NEA, might be of interest to some schools although it is really designed for students over the age of 16. The attention of readers is also drawn to three ASE publications, *Rethinking science* (**5.8**), *Rural Science: An applied view of science* (**7.2**) and the *Science and Technology in Society* materials (SATIS) (**6.7**).

A good example of a thematic approach being developed by an SSCR group is the Essex *Primary Approaches to Secondary Science* (PASS) material. They are not attempting to produce a complete course but intend to provide five exemplars of themes which can be treated in a very open-ended and student-centred way. They are 'Time', 'Litter', 'Tree leaves', 'Soil' and 'Metals'. They exemplify very well the point that themes and contexts both provide starting points for study and continue to be an integral element in that study. They are not just coincidental references to applications of scientific principles. The Essex work reflects some of the excellent ideas in the *Nuffield Science 5–13* scheme (**7.3**).

We would like to illustrate the short discussion above by referring in a little more detail to the rural science context. This has been the concern of a SSCR special interest group. Its membership includes representatives of six local working groups, three of which have already published their work (**7.4–7.6**), a TVEI representative from Devon, two LEA advisers and three members of the SSCR Central Team. They all feel that rural science should become part of mainstream science courses and that it could form a context for an integrated science course or a module within one. Their experiences as teachers have convinced them that it is a highly motivating context. It has social and environmental relevance and engages students in genuinely technological activities. They are compiling a joint report which will include advice on resources and INSET workshop materials for non-specialist teachers (**7.1**).

SECTION EIGHT

Current and future trends

This section is about the politics of curriculum change especially as it relates to science education. It is not concerned with party political dispute, with squabbles between central and local government or with the stresses and strains that worry the teaching unions and their members, important and perplexing though these matters may be for teachers. We are concerned here with the curriculum and, certainly as far as science is concerned, there seems to be very little disagreement among politicians about that.

Schools in the United Kingdom have traditionally enjoyed a considerable degree of autonomy and still do. Local authorities until relatively recently appeared neither to exercise nor to seek any significant control of the curriculum. Indeed the main influence outside the schools themselves came from the examination boards who reacted from time to time to pressures from various other institutions, not least the universities. Successive governments have felt uneasy about this somewhat anarchic state of affairs. The Bury LEA response (**8.1**) to DES circular 8/83 (**8.2**) describes some of the initiatives that have occurred in response to the situation.

> *The HMI surveys* Primary Education in England *(HMI 1978) and* Aspects of Secondary Education in England *(HMI 1979) encouraged . . . investigations and review. It was recognised, however, following the publication in January 1980 of the HMI document* A view of the curriculum *(HMI 1980) and the Secretaries of States' consultative document* A framework for the school curriculum *(DES 1980) that the Government had shifted the emphasis towards involvement in curriculum as a means of influencing the national system to meet national needs. This also appeared to demand the changing of attitudes, particularly since local authorities were being asked to formalise their curricular arrangements. There were feelings that the powers and duties given to governing bodies had not been generally effective and too much had been left to be determined within individual schools, and especially in secondary schools in response to the demands of examination syllabi. Although there were many examples of initiatives by advisory teams and through in-service training the view was developing that benefit could be gained if curricular aims and objectives were defined at institution level. Other factors, including falling rolls, were concentrating attention on matters of curriculum, staffing, standards and resources, and it was felt in discussions embracing all these matters that the definition of local curriculum responsibilities was likely to emerge.*
>
> *The task for a local education authority was therefore seen as the formulation of a clear and known policy for the curriculum offered in its schools, the provision of information as to how far the curriculum provision in schools was consistent with that policy, and, in consultation with teachers in the schools and within the resources available, planning future developments. It was also recognised that there was a curriculum for the school and a curriculum for the child and the two, especially in the upper years of secondary education, did not always coincide. So the debate about curriculum had to include not only structure but content.*

Suffolk Education Committee take up the story (**8.3**).

> *In October 1981, the Secretary of State for Education and Science, Sir Keith Joseph, issued Circular 6/81 which set out the views of the Secretary of State on a range of matters relating to the school curriculum. Briefly, it highlighted the local authority's responsibility for content and quality and school governors' responsibility for bringing together the views of teachers, parents and the local community. The* central role of heads and their staffs *(our emphasis) was also fully acknowledged. All these partners were expected to work towards the common end of securing a planned and coherent curriculum within the schools, taking account of national and local considerations and the needs of individual pupils.*
>
> *Authorities were therefore called upon:*
>
> *– to review their policy for the school curriculum in their area, and their arrangements for making their policy known to all concerned;*
> *– to review the extent to which current provision in the schools was consistent with that policy; and*
> *– to plan future developments accordingly within the resources available.*
>
> *Schools were called upon to set out in writing the aims which they pursued through the organisation of the curriculum and in teaching programmes; and to assess regularly how far the curriculum – in the school as a whole and for individual pupils – matched the stated aims.*
>
> *Governors were to encourage their schools, within*

the resources available, to develop their curricula in the light of what was said in the Government publication The School Curriculum (*DES, 1981*).

A subsequent DES curricular (**8.2**) called upon LEAs to respond and asked some specific questions in order to provide a structure for their responses. SSCR asked local authorities in England and Wales for copies of their responses to Circulars 6/81 (**8.4**) and 8/83 (**8.2**) and 67 replies were received. Northern Ireland was not expected to respond to these DES circulars but the Education and Library Boards have produced independent policy statements which were included in our survey.

There are three other publications which appeared during this time of soul searching by the educational establishment and which ought to be mentioned. They are the Schools Council working paper, *The practical curriculum* (**8.5**), *Curriculum 11–16* (**8.6**) – the famous HMI 'red book' – and *A view of the curriculum* (**8.7**). It was in *Curriculum 11–16* that HMI first mentioned the 'areas of experience' which they felt should contribute to every child's balanced curriculum. There were then eight of them and they subsequently added one more. They are:

the aesthetic and creative
the ethical
the linguistic
the mathematical
the physical
the scientific
the social and political
the spiritual and
the technological.

It is clear that this list has greatly influenced LEA thinking. These areas of experience have cross-curricular currency and science teachers should not concern themselves exclusively with the scientific one. We therefore urge every teacher to read their own LEA's curriculum document, the general statement as well as any specific document relating to science.

As enthusiasts for curricular reform we found the task of reading and analysing the statements rather tedious, at times frustrating and even depressing. They were mostly reactive rather than proactive but refreshing new ideas sometimes did come through, not least the Suffolk Science initiative to which we refer in Section 5 and elsewhere in this guide. A good deal of space was spent describing the *status quo* and, although there were of course some declarations of intent, it seemed to us that LEAs understandably tended to keep firm commitments to a minimum, presumably to allow them room for manoeuvre when they were subsequently called to account! All this is in the nature of political documents and we should not therefore be too disappointed in them. Rather we should welcome the fact that LEAs can respond so positively to proposals for change which gives hope that the more radical document *Science 5–16: A statement of policy* (**0.3**) will be equally productive. We have already referred to this in some detail in Section 4 but it is worth reminding readers at this point that in several places it expresses the hope that SSCR proposals will help to bring about the changes it seeks.

There is another source of information which we have consulted and which ought to be mentioned before we summarise the LEA statements. We have a complete set of HMI full inspection reports for the three years 1982–4 (**3.2**). These contain curriculum analyses and other data which we think provide a reasonably accurate picture of current timetable provision for science. They have been critically discussed in Section 3 and some examples examined in detail. Whereas these HMI reports described the current position in the schools visited, the LEA statements look ahead, however tentatively, to the future.

We summarise the LEA statements below. It should be remembered that most of them were general responses not specifically concerned with science and so it is probably not reasonable to expect very much detail. In some cases separate science statements were also made but we have not seen all of these, in many cases because they were not available when we did our trawl. Much of what they contain is compatible with the SSCR position. We just wish they would be a little braver and 'stick their necks out'! Perhaps *Science 5–16* and our reports will encourage them to do so.

To help with our analysis of the statements we recruited a team of volunteers to read selections of them. The readers were asked a series of questions and these are used as headings in the following summary.

A summary of LEA statements on curriculum policy

Is science specifically required throughout the years of compulsory education?

This was clear policy in most cases and implied in nearly all the others. Most recommended it at primary level but a few did not insist. Only one LEA seemed willing to condone the dropping of science altogether by some students in years 4 and 5 in the secondary school.

What time allocations were recommended?

The majority made no recommendations or were very vague. Where a policy was stated it was for between 10 per cent and 15 per cent in the first three secondary years and between 10 per cent and 30 per cent in years 4 and 5. In many cases the

status quo was clearly being described. A few recommended a *maximum* of 20 per cent or even 20 per cent science for all. Others who were not prepared to go that far did warn of the possible curricular imbalance for those students studying science for more than 20 per cent of curricular time at this stage.

What timetable recommendations were made for secondary science?

Apart from general references to the need for balance many LEAs made no recommendations. Those that did asked for compulsory science as part of the core in the first two years and usually the third year too. Many said that separate science subjects were the norm in year 3 but surprisingly few actually advised it. In years 4 and 5 science was nearly always seen as featuring as several separate subjects within an option pattern. However at least one science subject was usually required and some favoured a science core as well as options.

What arrangements were recommended for technological education?

Technology was frequently mentioned but not always in the context of science. It was usually not clearly defined. It was often compulsory (usually as CDT) in the first three secondary years and efforts were also being made to introduce it as part of the core in years 4 and 5. There was a clear recognition of the HMI perception of technology as one of the broad areas of experience.

When technology was related to science, sometimes only by implication, it was in a variety of ways. Projects were mentioned. There was frequent reference to electronics and, more generally, to cross-curricular work linking mathematics, science and craft. Aspects of technological awareness and the applications of science were mentioned. Problem solving in a technological context was quite often seen as important. Technology was sometimes mentioned in a societal context or as part of human achievement.

Technology is often part of the common curriculum in the early years. Later it is likely to be part of the option pattern, usually associated with CDT and sometimes under the TVEI umbrella.

Were any differences recommended in the curriculum or in timetable provision for different ability levels?

There were some general remarks about the need for differentiation. Several statements mentioned a need to make special provision for the gifted and for the less able but did not go into detail. Where specific suggestions were made it was usually for separate sciences for the more able and combined, integrated or applied science for the others. Occasionally 'modular science' was seen as appropriate for the less able! One statement said that examination passes should not be seen as the most important purpose of the curriculum.

Different timetable structures were not usually suggested although they were sometimes implied by limited option schemes. Occasionally there was extra mathematics, English, etc., on the timetable for the less able and this must obviously have affected the rest of their timetable. In passing it should be mentioned that the evidence of the HMI inspection reports is that the timetable is often very different in practice for the different ability ranges.

What recommendations were made about personal, social and moral education?

Nearly all the statements mentioned personal, social and moral education with varying degrees of emphasis but it was rarely related to science. In one case personal and social aims were mentioned in a science context with reference to the ASE policy statement *Education through science* (**1.2**). The cross-curricular nature of this area was often emphasised. One reference was made to 'the day to day problem solving processes of living'. We found this interesting because it implied that problem solving should be a concomitant part of the school curriculum.

What recommendations were made about health education?

Many of the statements mentioned it but a surprisingly large number did not. It was only rarely related specifically to science although it was often referred to as a cross-curricular theme which should find a place in various subject areas where appropriate.

What recommendations were made about continuity, coherence and progression?

Continuity was usually mentioned as being important at the primary/secondary interface but only rarely at the secondary/tertiary interface. Liaison meetings between staff in primary and secondary schools were strongly advised, as were curriculum links and good record keeping and management of the exchange of records.

Several references were made to progression and curricular coherence. The importance of curriculum balance and cross-curricular liaison were stressed. Again there were several mentions of the importance of good record keeping and coordination of assessment. Some statements called upon schools to undertake curriculum

reviews and stressed the importance of a common curriculum. Curriculum reviews should seek to order content in a rational way so as to fit in with how children learn at different stages of their development. One statement said that the traditional subject view was not always conducive to coherence and progression. Another saw TVEI as a force for coherence. Two statements specifically mentioned the dangers of opting away from science.

Was there any special mention of girls and science?

About half the statements explicitly mentioned equal opportunities for girls and one advocated positive discrimination in their favour. Most references were in general terms but in a few cases science was specifically mentioned usually to stress the need to attract girls to the physical sciences.

Was any special mention made of multicultural aspects of science education?

There were only a few mentions and indeed some of the statements did not mention multicultural education at all. This was surprising but may be because separate statements were published.

Was any special provision recommended for science for the handicapped?

A few statements made general reference to special needs but hardly any mentioned science specifically. Those references that were made were very detailed and couched in sensitive terms.

Was concept formation and learning theory mentioned?

The former was mentioned fairly frequently. One LEA warned of the dangers of trapping concepts within subject boundaries. Learning theory was mentioned only rarely and then usually obliquely in terms of teaching strategies. The learning environment was sometimes seen as important.

Was INSET mentioned?

There was frequent mention with varying emphasis. Science was often seen as a priority area, in one case because of teacher specialisation. Curriculum analysis was also seen as an important field. In-school INSET was mentioned with approval as was support from the advisory services. There was very little evidence that constructive thought had been given to the *quality* of INSET and to its form and purpose. Clearly LEAs will need to have developed a coherent and comprehensible view of the type of INSET required well before the introduction of the new DES INSET arrangements in 1987. School science departments and individual science teachers would also be well advised to give some careful thought to their needs and perhaps to discuss them with their LEA science advisers.

What recommendations were made about the organisation of the subject matter?

In most cases no recommendations were made except for vague exhortations about coordination and about coherence of the total curriculum. There was some support for a general move toward integrated or combined science especially in the early years. Several LEAs still see separate subjects as being appropriate for the most able and combined or integrated science for the others. One LEA recommended double subject science for the whole 11–16 age range.

Content reduction was not often explicitly mentioned but one LEA said that the acquisition of knowledge should not be allowed to dominate the teaching and learning process. Another asked its schools to provide a detailed statement of content and level of treatment in all curriculum areas.

What recommendations were made about course structure?

Apart from a suggestion that alternative structures might be explored this question was hardly ever addressed. Two mentioned modular courses and one mentioned thematic or issue based courses as being suitable for the less able.

What mention was there of skills, processes and attitudes?

There was extensive reference to them. Sometimes they were mentioned in broad terms in connection with curricular aims. In other cases they were specified in great detail. The recommendations were in line with SSCR proposals in *Towards the Specification of Minimum Entitlement: Brenda and friends* (**4.3**) and our other Curriculum Guides.

What recommendations were made about assessment and reporting?

Both continuous assessment and examinations were mentioned. Advice was given about using assessment schemes for evaluating courses and for matching teacher intentions to student achievement. Schools were reminded of the need to

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review their assessment procedures regularly. One LEA suggested the use of APU material or the like for diagnostic testing. The importance of record keeping was stressed and guidance was sometimes offered. There was frequent mention of profiling, graded tests and assessment of personal characteristics. Self-assessment was also mentioned. Effective communication with parents was seen as important.

Was there any mention of context-directed courses?

There were several references to microelectronics, control technology, modular technology and computer studies and occasional ones to information technology but these were more often seen as CDT subjects rather than science subjects. Environmental studies and rural studies or horticulture were also sometimes mentioned but again they were not always seen as part of students' science education.

What out of school or extra-curricular activities were mentioned?

There was very little mention of science clubs. The most commonly mentioned activity was work experience. School/industry liaison and link courses with further education were considered important. Schools were urged to make use of the environment; nature reserves, forest plots and weather stations received specific mention. Field studies and residential experience were popular. Some LEAs said that their schools made good use of museums, libraries and zoos. Community education and international contacts were mentioned. One LEA mentioned both special courses for gifted children and special units for those with behavioural problems.

In conclusion, we make four points which together summarise our view of the LEA statements. First, their quality varies but in general they seem somewhat nebulous. This may be intentional! Second, the statements are only starting points for LEAs. *Science 5–16* (**0.3**) requires them to formulate policies for science education and schools need these policies as frameworks for their planning. Third, it is to be hoped that LEAs formulate their policies through consultation both within *and outside* their own boundaries. The latter is important if cross-fertilization is to occur and insularity and discontinuity are to be prevented. Finally we are a little disappointed with those LEAs which do not express in their statements any new ideas on science in the curriculum. We realise that this may not mean that they do not have any ideas, because the documents relate to the whole curriculum and in many cases are couched in very general terms. We hope that SSCR in Phase 3 of its operations (1986–9) can help with formulating policies by acting as consultants and by providing an information network.

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The Secondary Science Curriculum Review (SSCR) was set up in 1981 to stimulate, through working groups of practising teachers, the development of science studies which would help to provide an appropriate science education for *all* young people growing up in a scientific and technological society — whatever their abilities or career intentions. Its concern was not only with the science curriculum — its contents, purposes, teaching methods and resources — but also with the role of science in general education and within the whole school.

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